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SUBJECT: Contaminant Transport During Storms Near Solid Waste Storage Areas 4 and 5

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Contaminant Transport During Storms near Solid Waste Storage Areas 4 and 5

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Prepared by the
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1. INTRODUCTION

The traditional view that relatively steady, diffuse groundwater flow is the major pathway for contaminants to streams has come under scrutiny recently. Recent studies suggest that during rainstorm events laterally moving water in the shallow subsurface is responsible for a significant fraction of the total contaminant load of streams. This intermittently saturated stormflow system is responsible for a significant release of contaminants from waste disposal areas. In a study of White Oak Creek and Melton Branch during FY 1988, Solomon et al. (1989) found that generally greater that 50% of contaminants were transported in stormflow versus groundwater flow during major storms.

The objective of this study is to investigate the release of subsurface contaminants to streams in and around ORNL waste management areas. In order to better understand the effect of intermittent stormflow in the shallow subsurface on contaminant transport from the waste management areas, time series of stream samples were collected during storm events from tributaries draining Solid Waste Storage Areas 4 and 5 (SWSA 4 and SWSA 5). Only a selected number of the samples were analyzed for tritium, strontium-90, and gamma-emitting radionuclides, in order to reduce analytical costs. The analytical results were combined with stream discharge data to determine the contaminant mass flow at the different sites.

Previous studies have found that relationships exist between contaminant concentration and stream discharge in some of the streams in the ORNL Reservation. Solomon et al. (1989) and Huff et al. (1982) developed rating curves from these relationships which could be used to estimate total contaminant releases (or mass flows) using only stream discharge data. An important goal of this study was to determine if relationships between contaminants and discharge exist at the chosen sites near SWSA 4 and SWSA 5. Baseline contaminant releases and present day concentration versus discharge relationships can be valuable tools in the future to evaluate changes in the total inventory of contaminants present within waste management areas (referred to as the source term). Establishing these releases and relationships is also important in order to properly assess the effectiveness of any future remedial action project.

2. METHODS

A. Selection of Sampling Locations

During FY 1988 stream samples had been collected during storms from White Oak Creek (WOC) at Monitoring Station 3 and from Melton Branch (MB) at Monitoring Station 4. In an attempt to better define subsurface contaminant releases, sampling sites on two smaller streams draining individual waste management areas were chosen for FY 1989.

In October, 1988, baseflow samples were collected from five small tributaries in the ORNL Reservation and analyzed for tritium. Two of the five streams, one on the southern edge of SWSA 4 and the other on east edge of SWSA 5, had very high concentrations (millions of pCi/L) of tritium. This was not surprising since SWSAs 4 and 5 are known to contribute significant amounts of tritium to the WOC watershed. SWSA 4 is also reported to be a significant source of strontium-90. Therefore, five sites in and around SWSAs 4 and 5 were chosen for this study to be sampled monthly during baseflow conditions. Rainstorm monitoring was focused on three of the five sites. The locations of the sites are shown in Figures 1 and 2.

1. Bathtubbing Trenches Discharge Site (BTT)

Contaminated groundwater emerges at seeps in an area in the southern portion of SWSA 4. The seeps are thought to be a result of groundwater collecting in waste-filled trenches to the point of overflowing at the topographically low end. The term bathtubbing is applied to this condition. The site was chosen in order to better determine the dynamics of subsurface stormflow and its interactions with waste-filled trenches.

2. MS1 and T2A Sites

A significant portion of the contaminants released from SWSA 4 are transported to White Oak Creek by a small tributary on the southern edge of SWSA 4. Two monitoring stations (MS1 and T2A) already established on the SWSA 4 tributary were chosen for this study. Strontium-90 releases from SWSA 4 have been investigated previously at the upstream station (MS1) and the downstream station (T2A). Huff et al. (1982) reported that a concentration-discharge relationship for Sr-90 existed at T2A before a flow diversion system was built in 1983 to divert runoff from the SWSA 4 catchment headwater. Following the diversion project the relationship was evaluated; however, only limited data encompassing relatively low flow conditions were used, because of problems with flume submergence at T2A by WOC flooding during periods of high flow (Melroy and Huff, 1985). Therefore, MS1 was chosen to examine stormflow conditions and any concentration-discharge relationships which might result from the release of tritium and Sr-90 from SWSA 4. Monthly baseflow samples were collected at both MS1 and T2A.

3. HRTF and HRTV Sites

A tributary of Melton Branch flows near to the Homogeneous Reactor Experiment site and then adjacent to the east edge of SWSA 5 before entering Melton Branch. Contaminated groundwater from SWSA 5 has been found to contribute significant amounts of tritium to this Melton Branch tributary (HRT) and thus to Melton Branch (Solomon et al., 1989). The last two monitoring sites for this study were chosen on HRT. The upstream site, HRTV, is located at a small v-notch weir approximately 300 m from the downstream site, HRTF, where a small temporary flume was installed. Stormflow monitoring was conducted at HRTF, since it is located approximately 30 m downstream from a seep which is responsible for a large percentage of the tritium released to HRT.

B. Sample Collection

During the period of January to May, 1989, monthly baseflow samples were collected from 3 sites (BTT, MS1, and T2A) in and just south of SWSA 4 (Figure 1) and from 2 sites (HRTF and HRTV) on the Melton Branch Tributary (HRT) just east of SWSA 5 (Figure 2).

A time series of samples have been collected during rainstorm events from 3 of the 5 sites: BTT, MS1 and HRTF. Occasionally grab samples from T2A and HRTV were also collected during storm flow conditions. The stream samples were generally collected with an ISCO automatic sampler. This sampler is equipped with a peristaltic pump and is capable of collecting up to 24 1-liter samples at a user-defined sampling interval. The tubing and sample bottles for each sampler were washed with a dilute (10%) HCL solution and rinsed several times with distilled water before sample collection.

At MS1 and HRTF, the sampler intake lines (flexible tygon tubing) were attached to PVC pipes driven into the streambed just below the flumes. Several small notches were made in the end of the tubing to act as strainers for preventing any large debris from entering the sampler.

At BTT, the water emerging from the seeps is collected in a bermed area of approximately 408 m^2 and is directed to a 6.1 m long pipe which discharges the water into a bucket at the edge of a ravine. The bucket has been filled halfway with cement in order to provide a stable collection basin. The intake line for the sampler is attached to the inside of a bucket.

Not all of the samples collected by the auto samplers were actually processed for analysis. Discharge data from portable data-loggers with pressure transducers were examined to cost-effectively select specific samples for analysis. In general, an attempt was made to collect samples at critical points in the stream hydrograph, such as just prior to stormflow, near peak flow, and after the discharge had returned to baseflow. Additional samples were also collected at intermediate times between these critical points on the stream hydrograph. The selected samples were filtered through in-line 0.45 um polycarbonate filters using a peristaltic pump and tygon tubing. The tygon tubing around the pump head was replaced whenever a group of samples were filtered from a different site. The filters with the suspended sediment were saved for gamma counting. Water samples collected from each site were processed together, in a chronological fashion. Each sample was divided into 2 aliquots: (1) a 100 mL aliquot (acidified to a pH < 2 using HCl) in a 200 mL wide-mouth polyethylene bottle for strontium-90 and gamma-emitting radionuclide analyses, and (2) a 200 mL aliquot in a polyethylene bottle for tritium analysis. Details on the analysis procedures for the stream samples and filters are described by Solomon et al. (1989).

In March, baseflow samples were also collected from sites BTT, MS1 and T2A for cations, organic and gross-alpha analyses. A filtered 50 mL aliquot (acidified to a pH < 2 using HNO3) was stored in a pre-cleaned polyethylene bottle to be analyzed for metals using inductively coupled plasma (ICP) spectroscopy. An unfiltered 500 mL aliquot (acidified to a pH < 2 using HNO3) was collected for gross-alpha. Aliquots for volatile and semi-volatile organics were collected in a 40 mL glass and a 1 L amber glass bottle, respectively, such that there were no air bubbles in the containers. These samples were submitted to the Analytical Chemistry Division of ORNL for analysis.

C. Hydrological Data

Hourly precipitation data for the rainstorm events was obtained from a Belfort weighing bucket rain gage associated with a meteorological station located in SWSA 4.

Discharge data were determined by a variety of methods partially depended on the sampling site.

1. BTT Site:

A small combination rectangular v-notch weir has been calibrated in the lab by measuring flow at various stages. The weir was placed in the discharge pipe through which the seep water leaves the bermed area in SWSA 4. The discharge pipe has an attached stilling well in which a pressure transducer was installed. Electronic data logging equipment recorded stage measurements at specified time intervals (typically 5 minute intervals during the storm events). Periodically, the site was inspected to compare the transducer determined stage and the stage determined by viewing the weir and stilling well scales, and the offset was recorded or the data logger readjusted. Stage data from the data logger was downloaded to a PC, and adjusted with the inspection points. Two rating equations were produced from the lab calibration data by curve fit techniques; one equation for the v-notch portion of the weir, Q in L/s = 00.04 - 0.02(stage in cm) + 0.038(stage)^2, and one for the rectangular portion, Q in L/s = -0.441 + 0.184(stage in cm) +0.028(stage)^2. Discharge was computed with the rating equations, using the corrected stage values. In addition, as a check on the stage determined discharges, actual discharge was measured occasionally at the site by bucket-gaging (i.e. measuring the time required to fill a 14.92 L bucket).

2. MS1 Site

At MS1 a stilling well was installed just upstream of an existing flume in order to obtain continuous discharge data. Stages were recorded with the pressure transducer (installed in the well) and electronic data logging equipment. Accuracy of the transducer determined stages was checked by periodically measuring the depth of water in the flume with a caliper. The offsets were recorded and used to correct recorded stage values. Discharge data were calculated from corrected stage values with an existing rating table (R. B. Clapp, personal communication). During the beginning of the study period, a Manning F-3000A Flowmeter (dipping type stage recorder) also existed at the site. Stage data collected from the Mannning was used to verify stage recorded by the transducer and data logging equipment. As an additional check on stage determined discharges, the site was occasionally bucket gaged.

3. T2A Site

No continuous discharge measurements were made at this site. When collecting grab samples, the depth in the flume, as indicated by the weir scale, was recorded. The weir scale values were converted to vertical depths using an empirically derived conversion factor. Discharge was calculated with these vertical depths, using an existing rating table (R. B. Clapp, personal communication).

4. HRTF Site

Unlike MS1 and T2A which had previously been established as monitoring stations, HRTF required the installation of a small temporary flume in order to obtain discharge data. A stilling well has also been installed at the site with the intake at the manufacturer designated measuring point. Stages were measured and recorded in the stilling well with a pressure transducer and electronic data logger. Stage values were checked periodically by measuring the depth of water with a caliper, and comparing it to the transducer determined stage. The offsets were recorded and used to correct the recorded stages. The corrected stage values and a rating table supplied by the flume manufacturer were used to calculate discharge.

5. HRTV Site

No continuous discharge measurements were made at this site. When collecting grab samples, the stage height was read from an existing staff gage and converted to discharge values using a predetermined rating equation, Q in L/s = 61.635(staff gage units)$^{2.347}$, (D. M. Borders, personal communication).

3. RESULTS

A. Baseflow Sampling

Discharge values at the time of monthly baseflow sampling for the sites BTT, MS1, T2A, HRTV, and HRTF are shown in Fig. 3. The lowest monthly discharge for the streams occurred in April, the driest month during the sampling period with only 58 mm of total precipitation, while precipitation for January, February, March and May ranged from 135 to 168 mm. The high discharge values in February probably do not represent baseflow conditions, because the time of sampling occurred only 3 days after a rainstorm event and stream discharge was likely still returning to baseflow.

Tritium and strontium-90 concentrations for the sites during the baseflow sampling are shown in Figs. 4 and 5. Strontium-90 concentrations were greatest in the seep water from the bathtubbing trench area ranging from about 16,000 to 30,000 pCi/L, while the concentrations ranged from 9,000 to 13,000 at MS1 and T2A. The Melton Branch tributary (HRT) had much lower Sr-90 concentrations ranging from about 200 to 700 pCi/L at sites HRTV and HRTF. The greatest H-3 concentrations were in both the SWSA 4 tributary and at HRTF, while BTT had significantly lower concentrations, and HRTV had concentrations near background (~1000 pCi/L). Dissolved Cs-137 concentrations were generally undetected at all sites except BTT where concentrations ranged from about 340 to 870 pCi/L. "Dissolved" Cs-137 is defined as that which passes through a 0.45 μm pore-size filter and, therefore, may include colloidal size fractions. Generally contaminant concentrations are greatest when discharge is lowest (April sampling). However, the Sr-90 concentration at BTT exhibits an opposite trend with concentrations being greatest when discharge in greatest.

Cation analysis results for samples collected in March and submitted to Analytical Chemistry are given in Table . March samples from the two sites, BTT and MS1, in and just south of SWSA 4 had gross-alpha values of 541 $\pm$ 54 and 35.1 $\pm$ 5.4 pCi/L, respectively. The sample from HRTF only had 1.35 $\pm$ 1.08 pCi/L gross-alpha. Concentrations of 18 ug/L 1,2-dichloroethene(total) and 8 ug/L trichloroethene were detected in the March sample from MS1.

B. Storms Sampled

In February 1989, three rainstorm events occurred: the first beginning the 16th which was soon followed by the second on the 20th and the third on the 21st. Even though the first and third rain events had similar amounts of precipitation, the intensity of the rain was quite different. The first rain was a slow gentle rain (36 mm total over a period of 2 days), while the second and third events had very intense rainfalls (33 mm total) (Fig. 6). The different rain event intensities are seen in the response of discharge at BTT and MS1, with the second and third hydrograph peaks being much sharper than the first (Fig. 6). Soil saturation conditions also likely played a role in the sharp rises seen in the second and third hydrograph peaks.

During these 3 storm events, 28 samples from BTT, 32 samples from MS1, and 5 grab samples from T2A were collected and processed for analysis. Samples were not collected from the Melton Branch tributary at HRTF, because the temporary flume had not yet been installed.

For the period of the 16th to the 24th of February, discharge at BTT began at a baseflow of about 6 L/min and reached 3 major peaks of about 80, 60 and 150 L/min. The third discharge peak actually exceeded the weir calibration for a brief period. Discharge at MS1 began at a baseflow of approximately 150 L/min and reached 3 major peaks of about 1400, 1100 and 4500 L/min. The stream stage recorded by the transducer and data logging equipment during the first hydrograph peak was checked with stage data collected by the Manning dipping stage recorder, and values were very comparable (Fig. 7).

During a rain event in March, 1989, (total precipitation of 44 mm) samples were collected from BTT, MS1 and T2A. However, only a limited number was collected at BTT due to malfunctions in the pressure transducer. Weather conditions caused freezing to occur in the stilling well and the diaphragm of the transducer to break. And, even though 15 samples were collected at MS1, most were not analyzed because of uncertainty in the stage measurements. Occasionally, during the rain event, the transducer determined stage was checked by measuring the actual depth in the flume. The transducer determined stage varied 1 to 3 cm from true depth.

A final series of samples were collected from BTT, MS1 and HRTF during a storm event in May, 1989, in which 53 mm of rain fell, most in a short period of time causing sharp rises in the stream discharges (Fig. 8).

Because of problems with the transducer and/or stilling well at MS1, only 8 grab samples were collected and processed. Only 2 grab samples were collected from T2A. A total of 15 and 14 samples were collected at BTT and HRTF, respectively. Samples were collected near but not during peak discharges because both the weir at BTT and the flume at HRTF were exceeded by the storm flow; therefore, actual peak discharge values were not obtained for a brief period of time. Discharge at HRTF increased from baseflow values of about 300 L/min and exceeded 9000 L/min for about 2 hours. Discharge at BTT increased from a baseflow of about 1 L/min and exceeded 140 L/min for about 30 minutes.

All contaminant concentrations and discharge values determined during this study are given in the Appendix. Bucket-gaged measurements made at BTT, MS1 and T2A during the study period are compared to the rating curves in Figs. 9 through 11. Discharge at BTT determined by the rating curves appears to be slightly greater than true discharge (bucket-gaged values). Bucket-gaged values at MS1 and T2A are limited to the lower portion of the curves but compare fairly well.

C. Contaminant Concentrations versus Time

Concentrations of H-3, Sr-90, dissolved Cs-137 and particulate-sorbed Cs-137 for samples collected at BTT throughout the rainstorm events in February are shown in Figs. 12 through 15. Tritium and Sr-90 concentrations of the May storm samples are shown in Figs. 16 and 17. Tritium concentrations are diluted; whereas, Sr-90 and Cs-137 concentrations generally increase as a result of rainstorms. Particulate-sorbed Cs-137 reached maximum concentrations when sharp peaks in discharge occurred.

Concentrations of H-3 and Sr-90 for samples collected at MS1 throughout the February events and at MS1 and HRTF for the May event are shown is Figs. 18 through 20. Concentrations of dissolved and particulate-sorbed Cs-137 were generally below detection at MS1 and HRTF. Both H-3 and Sr-90 are diluted in the streams during periods of increased stream discharge.

D. Contaminant Mass Flows versus Time

The instantaneous release of a contaminant in streams can be computed by multiplying contaminant concentration by the stream discharge. This release will be referred to as the contaminant mass flow. Even though the concentration of a contaminant often decreased during the storm events, the mass flow of the contaminant exhibited a significant increase (Tables 2 through 5).

During the first storm event in February, H-3, Sr-90 and dissolved Cs-137 releases (mass flows) at BTT increased from background values by about 11, 13 and 39 times, respectively (Fig. 21). Even during the third storm event in February, when rainfall and runoff were intense, mass flows of H-3 and Sr-90 roughly doubled during a 1 hr period. During the May storm, H-3 and Sr-90 mass flows increased by at least 21 and 34 times, respectively. The mass flow of dissolved Cs-137 exhibited a significant increase during the first February storm, but brief decreases during the second and third events at BTT (Fig. 22).

During the February storm events H-3 and Sr-90 mass flows at MS1 exhibited increases near 5 times that of background values (Fig. 23). However, during the May storm these contaminant mass flows increased near 40 times that of background values (Fig. 24). Tritium and Sr-90 mass flows at HRTF exhibited increases near 4 times that of background during the May storm event (Fig. 25).

E. Contaminant Concentrations versus Stream Discharge

Concentrations of H-3, Sr-90 and Cs-137 as functions of stream discharge at BTT are shown in Figs. 26 through 29. At BTT poor relationships exist between the contaminants and discharge. When examining the H-3 data of BTT some relationships are apparent for individual rain events. Generally, dilution occurs as stream discharge increase. The Sr-90 and Cs-137 concentration-discharge relationships for BTT indicate a general increase in concentration occurs as stream discharge increases.

Tritium and Sr-90 concentration-discharge relationships are more defined at MS1 as shown in Figs. 30 and 31. The following inverse exponential relationships were determined using the least squares regression fit with the greatest r^2 value:

for H-3 $\quad$ Concentration(nCi/L) = $A*e^{B*Discharge(L/min)}$

A = 12708
B = -3.73E-4
The square root of the coefficient of determination = 0.82 for a sample size of 40.

for Sr-90 $\quad$ Concentration(pCi/L) = $A*e^{B*Discharge(L/min)}$

A = 11999
B = -2.52E-4
The square root of the coefficient of determination = 0.84 for a sample size of 46.

These relationships were determined using the entire set of concentration and discharge values. As seen in Figs. 32 and 33, somewhat different relationships exist for individual rainstorm events.

Tritium and Sr-90 concentration-discharge relationship were well defined for HRTF, although the data are limited to one storm event (Figs. 34 and 35). The following relationships were determined at HRTF using the a least squares regression fit:

for H-3 $\quad$ Concentration(nCi/L) = $A*Discharge(L/min)^B$

A = 218321
B = -0.61
The square root of the coefficient of determination = 0.98 for a sample size of 16.

for Sr-90 $\quad$ Concentration(pCi/L) = $A*Discharge(L/min)^B$

A = 5537
B = -0.42
The square root of the coefficient of determination = 0.97 for a sample size of 16.

During low flow conditions, concentrations of Sr-90 at HRTV were lower than at HRTF, yet during greater discharge the Sr-90 values seem to fit the relationship curve defined downstream at HRTF (Fig. 35).

4. DISCUSSION

A. Sites in and near SWSA 4

An increase in laterally moving water in the shallow subsurface during rainstorm events is evident in the response of the water discharged from the bathtubbing trench area in SWSA 4. During the first storm in February this subsurface flow component at BTT can be easily seen in the lag time of the discharge peak (Fig. 6). Discharge at BTT reached a maximum 11 hours after the discharge peak at MS1 which is lower in the watershed. The discharge responses indicate that there is a significant subsurface stormflow component at BTT, while discharge at MS1 seems to be dominated more by surface runoff. Even though the subsurface stormflow may not be apparent when examining hydrographs of sites other than BTT, the significant increases in contaminant releases (mass flows) at all the sites during storms reveals that there is subsurface stormflow causing an increase of contaminant migration from the burial grounds to the streams.

The rapid increase in contaminant mass flows at BTT during the second and third storms in February indicate just how rapid subsurface stormflow actually is. However, another mechanism may contribute to the rapid increase in Sr-90 mass flow. A large input of fresh water (intense rainfall) causes significant decrease in Sr-90 concentration of the seep water. As a result, desorption of Sr-90 from the surface over which the seep water flows would occur until a new equilibrium is established. The mobilization of Sr-90 from stream sediments of Melton Branch and White Oak Creek during rainstorm events was also suggested by Solomon et al (1989) because of a high correlation between Sr-90 and stable Sr. The decreases in dissolved Cs-137 mass flow during the periods of intense precipitation (Fig. 21) are likely a result of sorption onto the suspended sediments mobilized by the intense discharge. Since Cs-137 is strongly and irreversibly sorbed, the increase of suspended sediments would provide abundant sorption sites for the dissolved Cs-137. This hypothesis is supported by the large increases of particulate-sorbed Cs-137 seen at the time of intense discharge (Fig. 15).

Results from the sites BTT, MS1 and T2A suggest that there is some sort of patchwork of contaminant sources in SWSA 4. Comparison of baseflow contaminant mass flows at BTT and MS1 reveal that while the bathtubbing trench area in SWSA 4 contributes <0.1% to the SWSA 4 H-3 release, the BTT area is a significant source of Strontium-90. During monthly baseflow sampling, Sr-90 released at BTT averaged approximately 15% of the Sr-90 measured at MS1. The bathtubbing trench area appears to have a greater contribution during periods of increased discharge. For example, approximately 14.6 mCi of Sr-90 was released from BTT during the period of rainstorms in February (Table 6). This release is approximately 24% of the 60.1 mCi measured at MS1 during the same time period.

The large amounts of H-3, as well as the remaining percent of Sr-90, released from SWSA 4 seem to be dominantly from sources between the bathtubbing trench area and the MS1 site. There does not appear to be any significant contaminant contributions between MS1 and T2A. Both discharge and contaminant concentrations were typically sightly lower at the downstream location, T2A. The lower concentrations may be a result of sorption of contaminants onto the stream bed or the addition of water with lower contaminant concentrations. The greater discharge at the upstream site, MS1, indicates that the stream is influent at some locations between the two sites.

Recent studies (Solomon et al., 1989; Melroy and Huff, 1985; Huff et al., 1982), as well as this study, have found that typically dissolved contaminant concentrations in stream water are lower (diluted) during periods of increased discharge. However, there is a significant difference in the Sr-90 concentration-discharge relationship found at BTT. The results from both the monthly sampling and storm sampling at BTT indicate that there is a significant source of Sr-90 in the trenches above the water table. During wetter periods, especially during rainstorms, a rise in the water table, as well as an increase in lateral subsurface flow occurs inundating the buried waste and mobilizing more Sr-90 and also Cs-137. As mentioned earlier the bathtubbing trenches are not a significant source for H-3. There may have never been significant quantities of H-3 buried in these trenches, or perhaps the conservative (non-reactive) geochemical behavior of H-3 has allowed much of it to be rinsed from the trenches in this area.

B. Sites East of SWSA 5

Because H-3 concentrations in the Melton Branch tributary at the HRTV site are near background levels, the large H-3 mass flow at the downstream site, HRTF, is a result of contaminated groundwater from SWSA 5 entering the stream between these two sites. In a previous study Solomon et al. (1989) found that most of the H-3 is entering as seeps at discrete locations. Strontium-90 mass flow also increases between these two sites indicating that transport of Sr-90 is occurring from SWSA 5. However, the elevated Sr-90 concentrations at HRTV indicate that there is a significant source of Sr-90 upstream. A survey of Sr-90 associated with streambed gravels (Cerling and Spalding, 1982) indicates that an inactive waste impoundment at the Homogeneous Reactor Experiment site is the likely upstream source of Sr-90. In 1988, water from a downgradient monitoring well for the impoundment had a Sr-90 concentration close to 30,000 pCi/L (Solomon et al., 1989) This upstream Sr-90 source contributed approximately 32% of the Sr-90 mass flow at HRTF during baseflow sampling in April and May. However, during two May stormflow samplings, 73% and near 100% of the Sr-90 mass flow was entering upstream of HRTV. Thus, apparently subsurface stormflow has a far greater affect on the Sr-90 source upstream from HRTV than it has on the source in SWSA 5.

5. SUMMARY

Data collected during this study indicates that contaminant transport from SWSA 4 and SWSA 5 increases during rainstorm events. Even though dissolved contaminant concentrations typically experienced a dilution during the stormflow, there were significant increases in contaminant releases (mass flows). These increases indicate that subsurface stormflow is occurring through the burial grounds mobilizing and transporting significant quantities of contaminants to the streams.

Analyses of samples collected from the two sites on the SWSA 4 tributary, MS1 and T2A, and from the bathtubbing trench site, BTT, in SWSA 4 indicate that the primary source area for H-3 is upstream of MS1 and below BTT, while a significant source of Sr-90 is in the bathtubbing trench area in the southern portion of SWSA 4. During rainstorms in February, 1989, approximately 24% of the Sr-90 mass flow in the tributary just south of SWSA 4 was released from the bathtubbing trenches. Increasing Sr-90 and Cs-137 concentrations during periods of stormflow at BTT, indicate that the waste-filled trenches are very conductive to the subsurface stormflow allowing increased contact and mobilization of contaminants.

There are also different source areas contributing to the contaminants in the Melton Branch tributary just east of SWSA 5. While essentially all of the H-3 mass flow at HRTF is a result of contaminated groundwater from SWSA 5 seeping into the stream, a significant portion of the Sr-90 mass flow appears to be coming in upstream from an inactive waste impoundment at the Homogeneous Reactor Experiment site. Collecting stream samples during baseflow along a transect upstream of HRTF would be very useful in locating areas where groundwater loaded with Sr-90 is entering the stream.

Contaminant concentration-discharge relationships exist for H-3 and Sr-90 at HRTF on the Melton Branch tributary just east of SWSA 5. Because of time limitations HRTF was only sampled during one rainstorm event; therefore, further storm sampling should be carried out at this site to better define the contaminant-discharge relationships that exist. Annual contaminant releases could be estimated using these relationships and discharge data with a program developed by Solomon et al. (1989). Information on the nature of contaminant release from SWSA 5 could be gained if these relationships and annual releases at HRTF are compared to those that exist lower in the watershed in Melton Branch.

Contaminant concentration-discharge relationships also exist for H-3 and Sr-90 at MS1 on the SWSA 4 tributary. Future analysis should be conducted on the relationships found at MS1 just south of SWSA 4. If reliable discharge data could be obtained, annual contaminant releases from SWSA 4 could be estimated using these relationships and the program developed by Solomon et al. (1989). Maintenance on the stilling well at MS1 is needed so that reliable stage data can be recorded. A comparison of the present Sr-90 concentration-discharge relationship at MS1 with that established for Sr-90 at T2A by Huff et al. (1982) could be useful in evaluating the effectiveness of the flow diversion system built around SWSA 4 in 1983.

In conclusion monitoring of streams adjacent to waste management areas has proven to be a very useful tool in locating significant areas of contaminant releases, and thus, helping to minimizing any future remedial action by knowing what areas need the primary focus. Furthermore, the contaminant concentration-discharge relationships established in this study can be utilized to help determine the effectiveness of future remedial actions.

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TABLE 1.

CATION ANALYSIS RESULTS (ug/L)
FOR MARCH MONTHLY BASEFLOW SAMPLING

	BTT	MS1	HRTF
Ag	< 5	< 5	< 5
Al	560	480	340
As	< 60	< 60	< 60
B	< 80	110	< 80
Ba	290	100	41
Be	25	25	25
Ca	130000	87000	51000
Cd	11	12	12
Co	< 3	< 3	< 3
Cr	19	16	14
Cu	< 10	< 10	< 10
Fe	87	13	12
Ga	< 300	< 300	< 300
Li	< 200	< 200	< 200
Mg	21000	15000	10000
Mn	25	70	350
Mo	< 40	< 40	< 40
Na	29000	13000	7300
Ni	45	25	5.6
P	< 300	< 300	< 300
Pb	< 50	< 50	< 50
Sb	< 30	< 30	< 30
Se	< 60	< 60	< 60
Si	3800	3100	3000
Sn	< 50	< 50	< 50
Sr	250	180	110
Ti	< 20	< 20	< 20
V	< 4	< 4	< 4
Zn	< 8	< 8	< 8
Zr	< 20	< 20	< 20

TABLE 2.

CONTAMINANT MASS FLOWS AT BTT DURING FEBRUARY AND MAY STORMS

LOCATION	DATE	TIME	DISCHARGE L/min	H-3 pCi/sec	Sr-90 pCi/sec	Dissolved Cs-137 pCi/sec
BTT	02/16/89	11:00	5.32		2354	27
BTT	02/16/89	20:00	6.72	7087	3048	36
BTT	02/17/89	04:00	12.54		5376	29
BTT	02/17/89	09:00	18.78	17583	7373	38
BTT	02/17/89	14:00	21.06		8924	79
BTT	02/17/89	18:00	31.38	28852	12562	72
BTT	02/17/89	22:00	49.86	43086	20576	265
BTT	02/18/89	02:00	64.86	60887	32784	728
BTT	02/18/89	06:00	75.18	73293	39658	1116
BTT	02/18/89	10:00	77.28	74555	40505	1373
BTT	02/18/89	14:00	68.1	66853	37156	1397
BTT	02/19/89	00:00	58.8	56820	32941	1119
BTT	02/19/89	12:00	37.5	37080	20413	694
BTT	02/20/89	04:00	24.6	23014	13363	528
BTT	02/20/89	10:00	49.62	40697	19383	139
BTT	02/20/89	14:00	30	29143	15724	597
BTT	02/21/89	02:00	39.54	35952	21285	975
BTT	02/21/89	03:00	130.32	76044	38430	169
BTT	02/21/89	06:00	85.02	60102	40969	1165
BTT	02/21/89	10:00	78.99	62102	44074	2181
BTT	02/21/89	13:00	66.36	52953	37399	2285
BTT	02/21/89	16:00	90.42	73719		3230
BTT	02/21/89	19:00	76.86	65590	40263	2904
BTT	02/22/89	02:00	67.26	56701	32836	2431
BTT	02/22/89	10:00	49.8	41148	23956	1693
BTT	02/23/89	06:00	33.36	26501	15546	868
BTT	02/24/89	13:10	15.71	13712	7738	227
BTT	05/04/89	14:00	0.74	597	175	
BTT	05/05/89	10:00	0.74	540	173	
BTT	05/05/89	13:00	20.82	5049	3387	
BTT	05/05/89	15:00	19.68	7508	4391	
BTT	05/05/89	16:00	6.96	2793	1657	
BTT	05/05/89	20:00	6.19	3829	1801	
BTT	05/05/89	21:00	21.78	10371	5538	
BTT	05/06/89	00:00	19.69	12776	5922	54
BTT	05/06/89	04:00	9.54	7041	3067	
BTT	05/06/89	07:00	2.53	1892	792	
BTT	05/06/89	09:00	9.23	6706	2878	
BTT	05/06/89	15:00	7.78	5948	2381	
BTT	05/07/89	03:00	6.96	5258	2108	10
BTT	05/07/89	21:00	6.19	4709	1872	12
BTT	05/08/89	13:45	3.38	2590	1038	11

TABLE 3.

H-3 AND SR-90 MASS FLOWS AT MS1 DURING FEBRUARY AND MAY STORMS

LOCATION	DATE	TIME	DISCHARGE L/min	H-3 nCi/sec	Sr-90 pCi/sec
MS1	02/13/89	15:00	184.68	43301	38669
MS1	02/16/89	11:00	147	33082	31759
MS1	02/16/89	20:00	167.7		35696
MS1	02/17/89	06:00	254.16	57703	56182
MS1	02/17/89	09:00	372.9	64313	75129
MS1	02/17/89	11:00	536.04		99512
MS1	02/17/89	14:00	494.22	76802	85984
MS1	02/17/89	17:00	752.1		113828
MS1	02/17/89	20:00	1083.42	168616	155548
MS1	02/17/89	22:00	1365.6	212009	177478
MS1	02/18/89	00:00	1219.5	194327	153749
MS1	02/18/89	04:00	952.26	154234	127197
MS1	02/18/89	08:00	780.66	127248	113489
MS1	02/18/89	16:00	549.3	88337	95338
MS1	02/19/89	04:00	397.2	64386	76660
MS1	02/19/89	16:00	305.46	50859	64044
MS1	02/20/89	04:00	262.68	45479	55184
MS1	02/20/89	10:00	640.32	93978	132029
MS1	02/20/89	12:00	716.28	73001	127701
MS1	02/20/89	16:00	454.5	66509	87467
MS1	02/21/89	02:00	362.4	62520	67981
MS1	02/21/89	03:00	1033.62	139987	166625
MS1	02/21/89	04:00	4480.14	206908	376973
MS1	02/21/89	06:00	2483.88	268632	293154
MS1	02/21/89	08:00	1851.84	191511	214959
MS1	02/21/89	10:00	1252.32	138987	156670
MS1	02/21/89	13:00	892.8		130288
MS1	02/21/89	16:00	700.68	80508	110715
MS1	02/22/89	00:00	475.68	58897	89495
MS1	02/22/89	10:00	346.92		69605
MS1	02/22/89	20:00	298.32	39398	61801
MS1	02/23/89	12:00	275.76		58047
MS1	02/24/89	13:25	275.76	39962	57893
MS1	05/04/89	15:00	17.7	4246	3531
MS1	05/05/89	14:00	1442.4	122917	162818
MS1	05/05/89	15:15	1203.18	145625	141973
MS1	05/05/89	17:00	924.6	146025	118950
MS1	05/06/89	08:30	336.9	78009	48562
MS1	05/06/89	11:00	284.76	68698	43410
MS1	05/06/89	18:00	191.82	50337	31444
MS1	05/08/89	13:00	71.88	21052	13434

TABLE 4.

H-3 AND SR-90 MASS FLOWS AT T2A DURING FEBRUARY AND MAY STORMS

LOCATION	DATE	TIME	DISCHARGE L/min	H-3 nCi/sec	Sr-90 pCi/sec
T2A	02/13/89	1500	82.8	14654	12324
T2A	02/17/89	920	434.76	67641	63318
T2A	02/17/89	1410	564.72	73470	81536
T2A	02/18/89	1545	700.68	88998	88068
T2A	02/21/89	1603	1007.34	92608	117056
T2A	02/24/89	1345	127.89	14375	18180
T2A	05/06/89	10:40	386.52	64343	47665
T2A	05/08/89	14:15	55.95	10905	8117

TABLE 5.

H-3 AND SR-90 MASS FLOWS AT HRTF AND HRTV DURING MAY STORM

LOCATION	DATE	TIME	DISCHARGE L/min	H-3 nCi/sec	Sr-90 pCi/sec
HRTF	05/04/89	14:00	295	36482	2952
HRTF	05/05/89	10:00	439	44218	3768
HRTF	05/05/89	11:00	1601	97765	7443
HRTF	05/05/89	12:00	8074	158254	17057
HRTF	05/05/89	15:00	7609	124020	15002
HRTF	05/05/89	17:00	6266	114884	15003
HRTF	05/05/89	20:00	3986	84831	11788
HRTF	05/05/89	21:00	6353	101751	13420
HRTF	05/05/89	23:00	4121	82771	15672
HRTF	05/06/89	04:00	2920	68527	9870
HRTF	05/06/89	10:00	2234	64276	6608
HRTF	05/06/89	15:00	1561	56359	6156
HRTF	05/06/89	23:00	1185	52733	5340
HRTF	05/08/89	12:15	604	41962	4340
HRTV	05/05/89	12:00	4430	64.24	12478
HRTV	05/06/89	10:30	1115	23.60	7066
HRTV	05/08/89	12:10	315	6.14	1686

TABLE 6.

TOTAL CONTAMINANT RELEASES DURING RAINSTORM EVENTS (mCi)

	BTT			MS1		T2A	
	Sr-90	H-3	Cs-137	Sr-90	H-3	Sr-90	H-3
1st Feb Storm (41 hr)	6.29	11.63	0.19	26.1	26027		
2nd & 3rd Feb Storms (57 hr)	8.30	14.11	0.45	34.0	24814		
May Storm (47 hr)	0.64	1.48		17.9	20724	2.22	19886

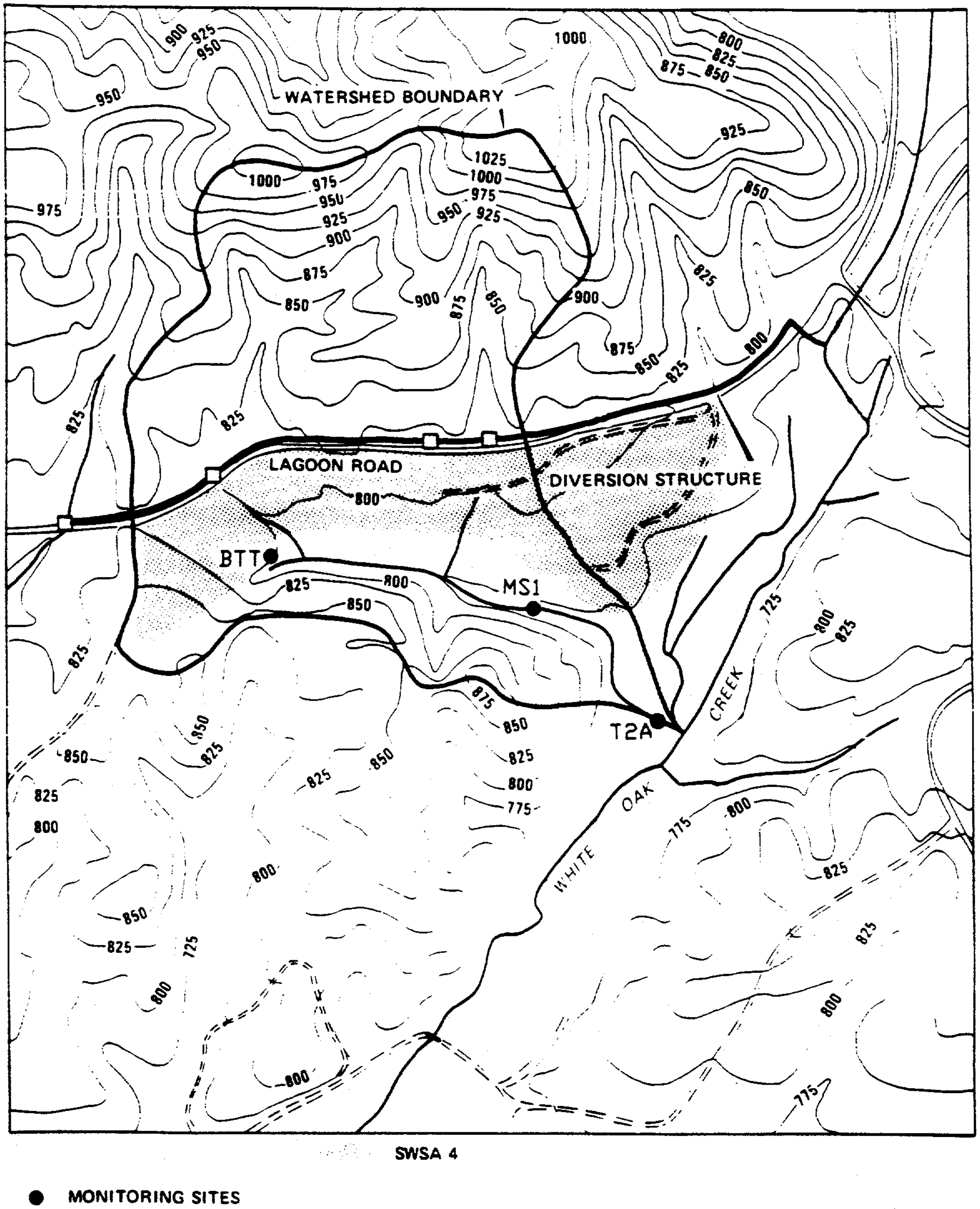

Fig. 1. Map of Solid Waste Storage Area 4 (SWSA 4), showing monitoring sites on the SWSA 4 tributary and in the bathtubbing trench area.

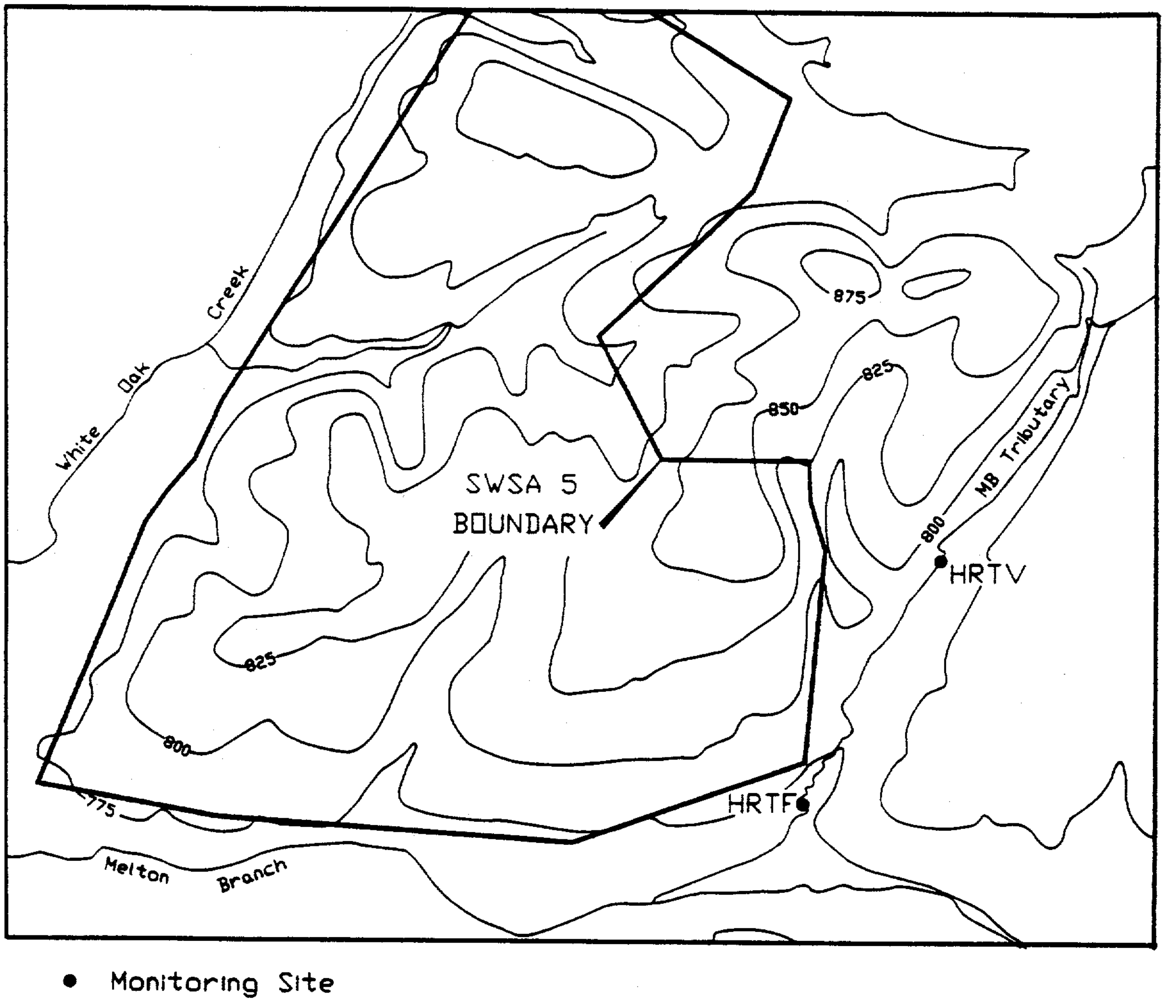

Fig. 2. Map of Solid Waste Storage Area 5, showing monitoring sites on Melton Branch tributary.

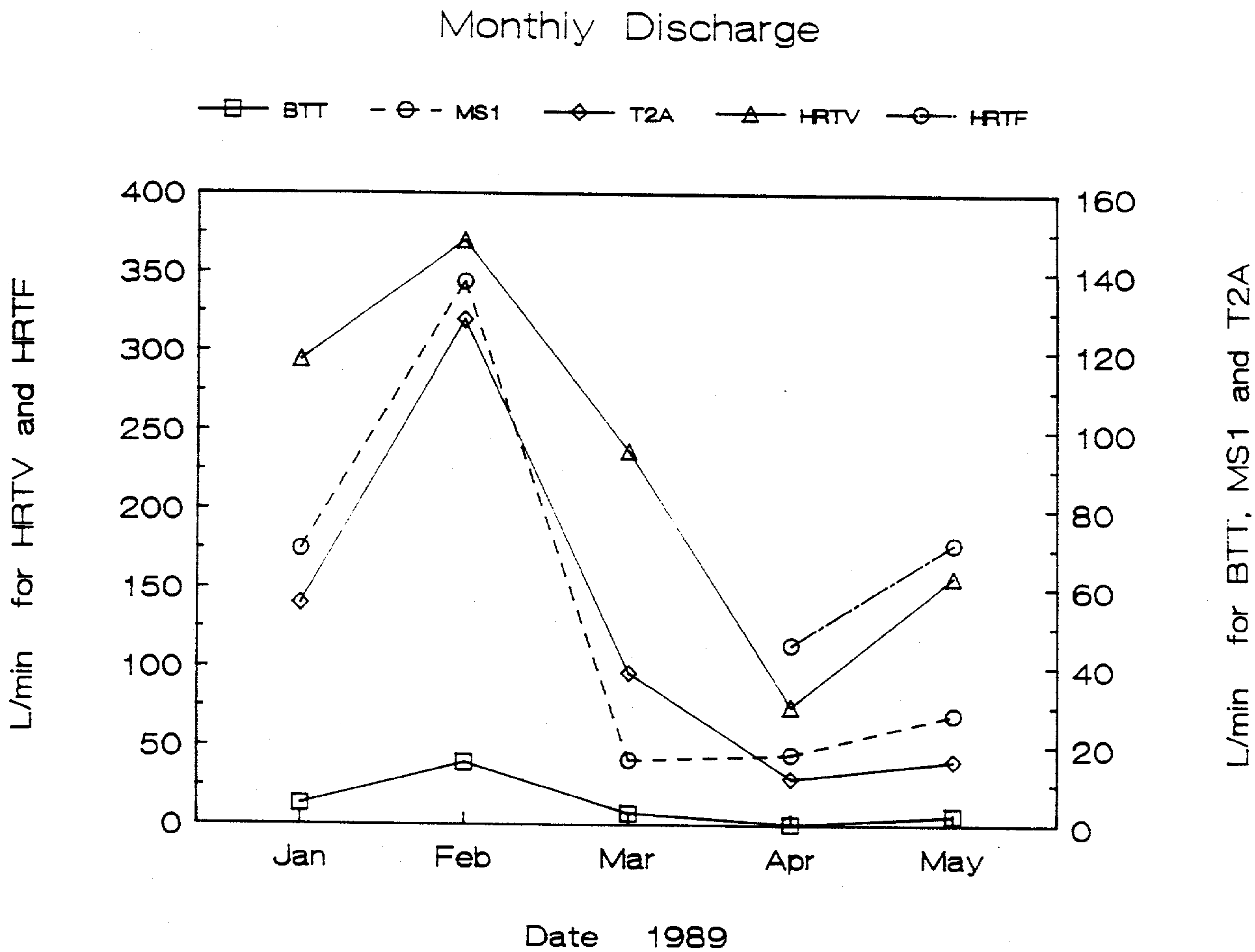

Fig. 3. Discharge values during monthly baseflow sampling for all sites.

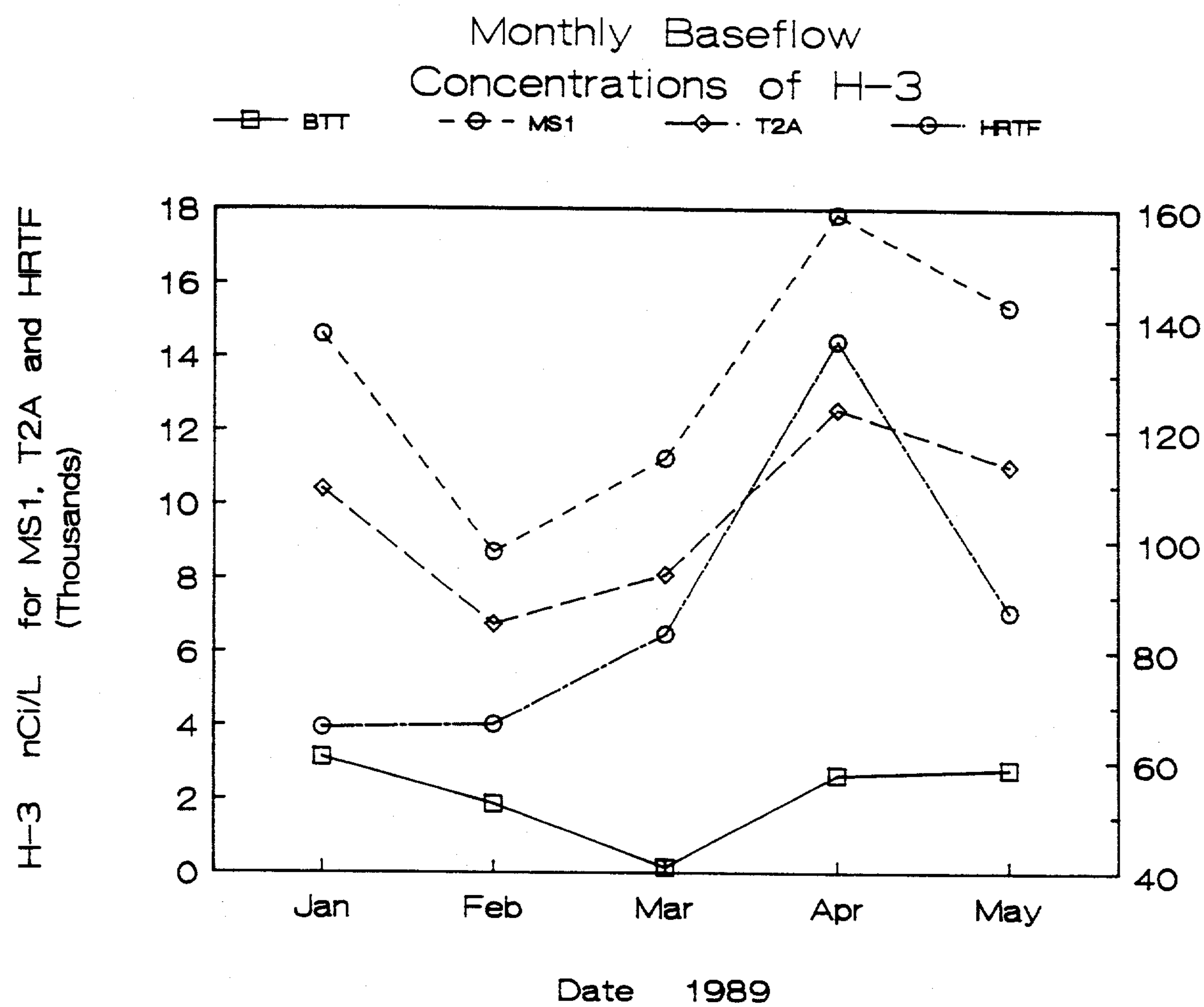

Fig. 4. Tritium concentrations during monthly baseflow sampling for sites BTT, MS1, T2A and HRTF.

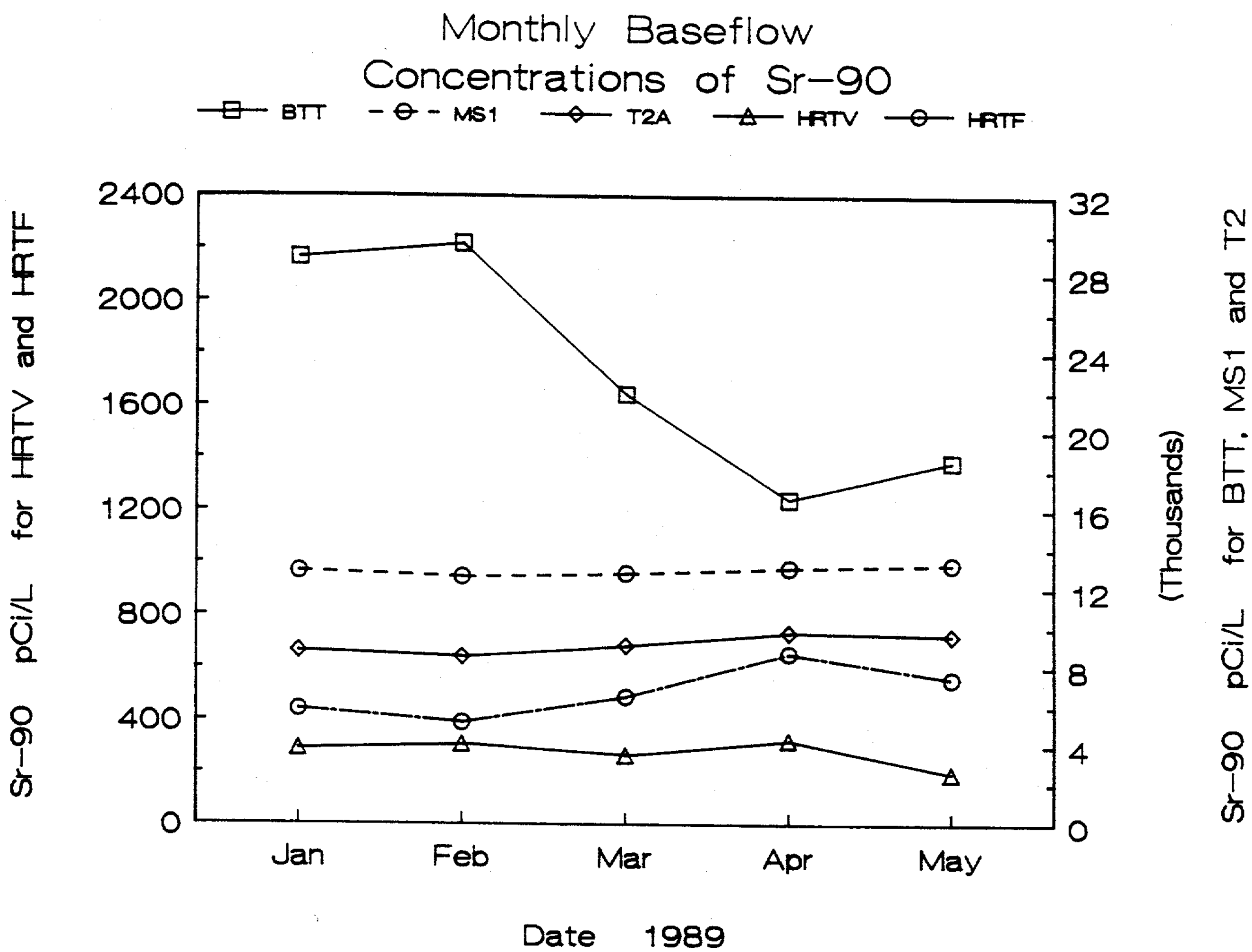

Fig. 5. Strontium-90 concentrations during monthly baseflow sampling for all sites.

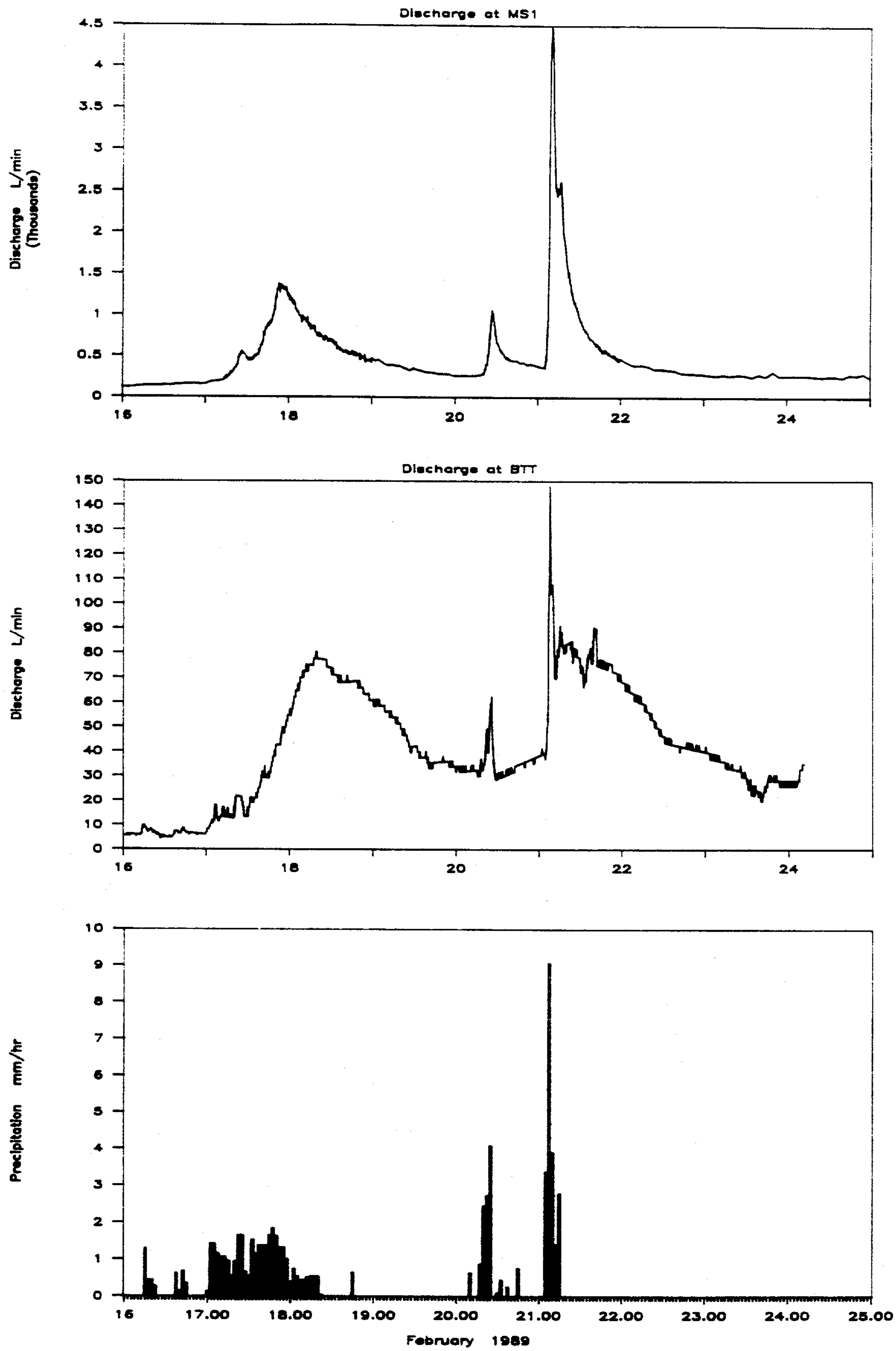

Fig. 6. Hydrographs for BTT and MS1, and precipitation during February rainstorm events.

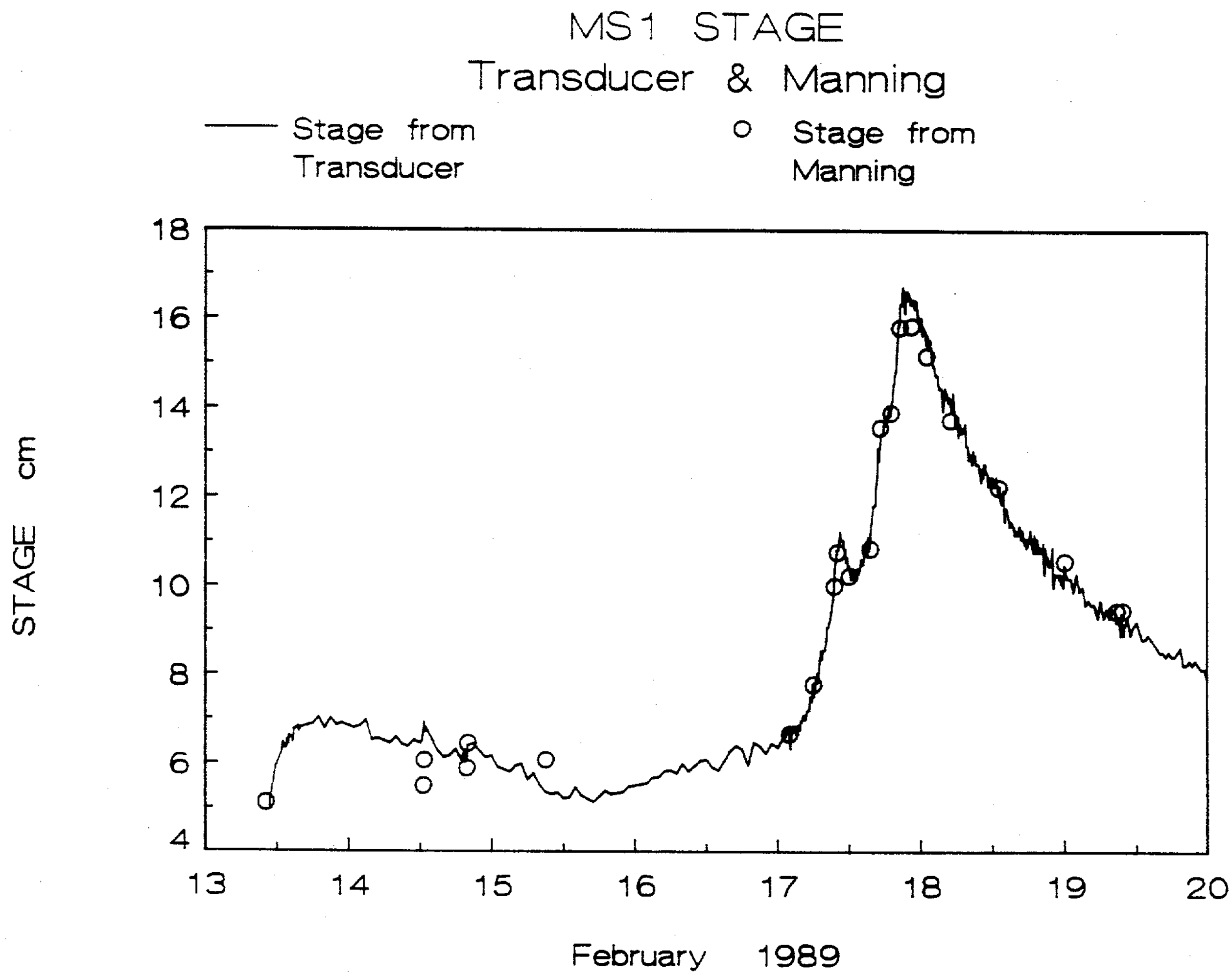

Fig. 7. Comparison of stage from Manning dipping stage recorder with the stage recorded by the transducer and data logging equipment at MS1 during the first February storm event.

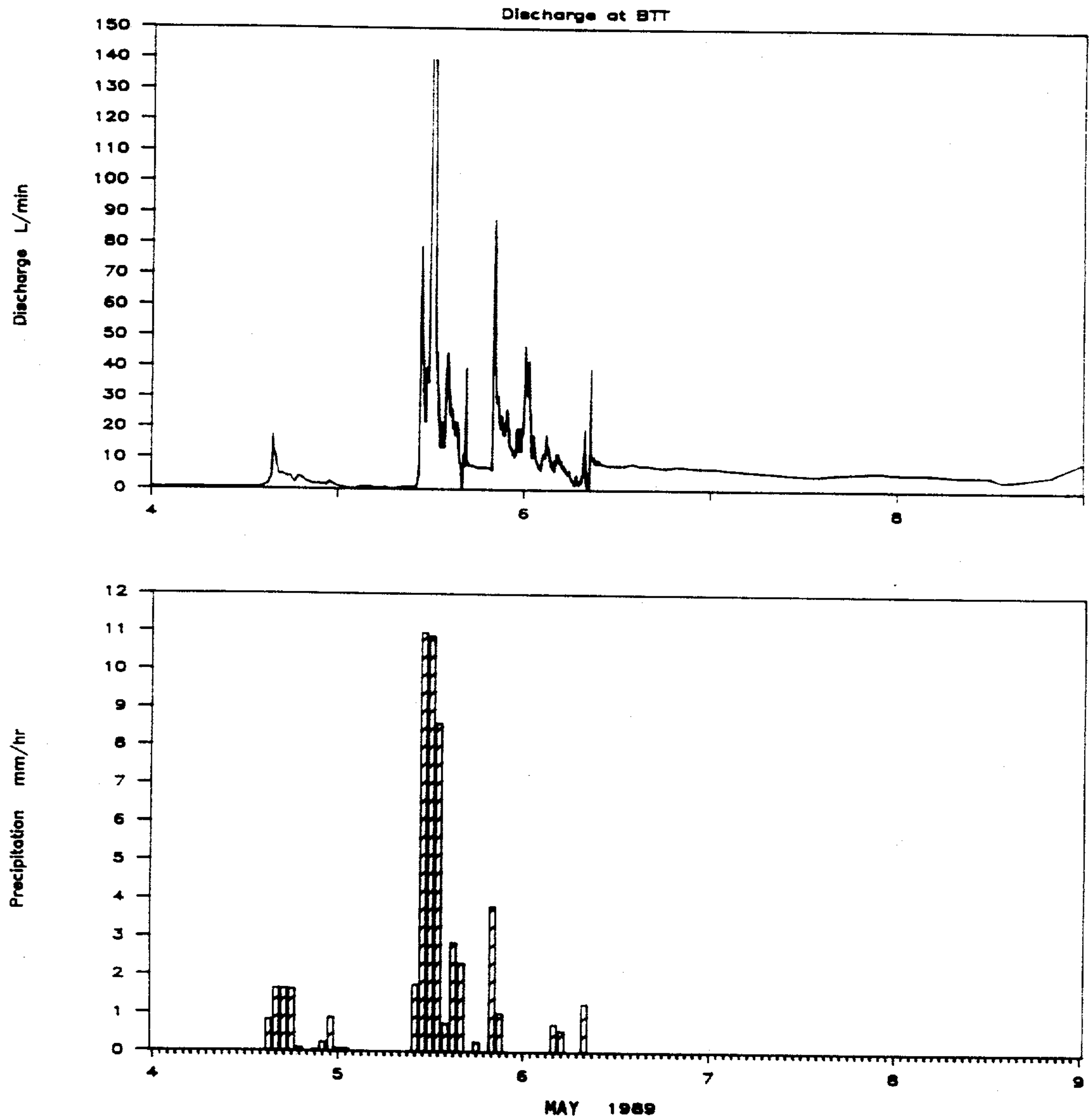

Fig. 8. Hydrograph for BTT and precipitation during May rainstorm event.

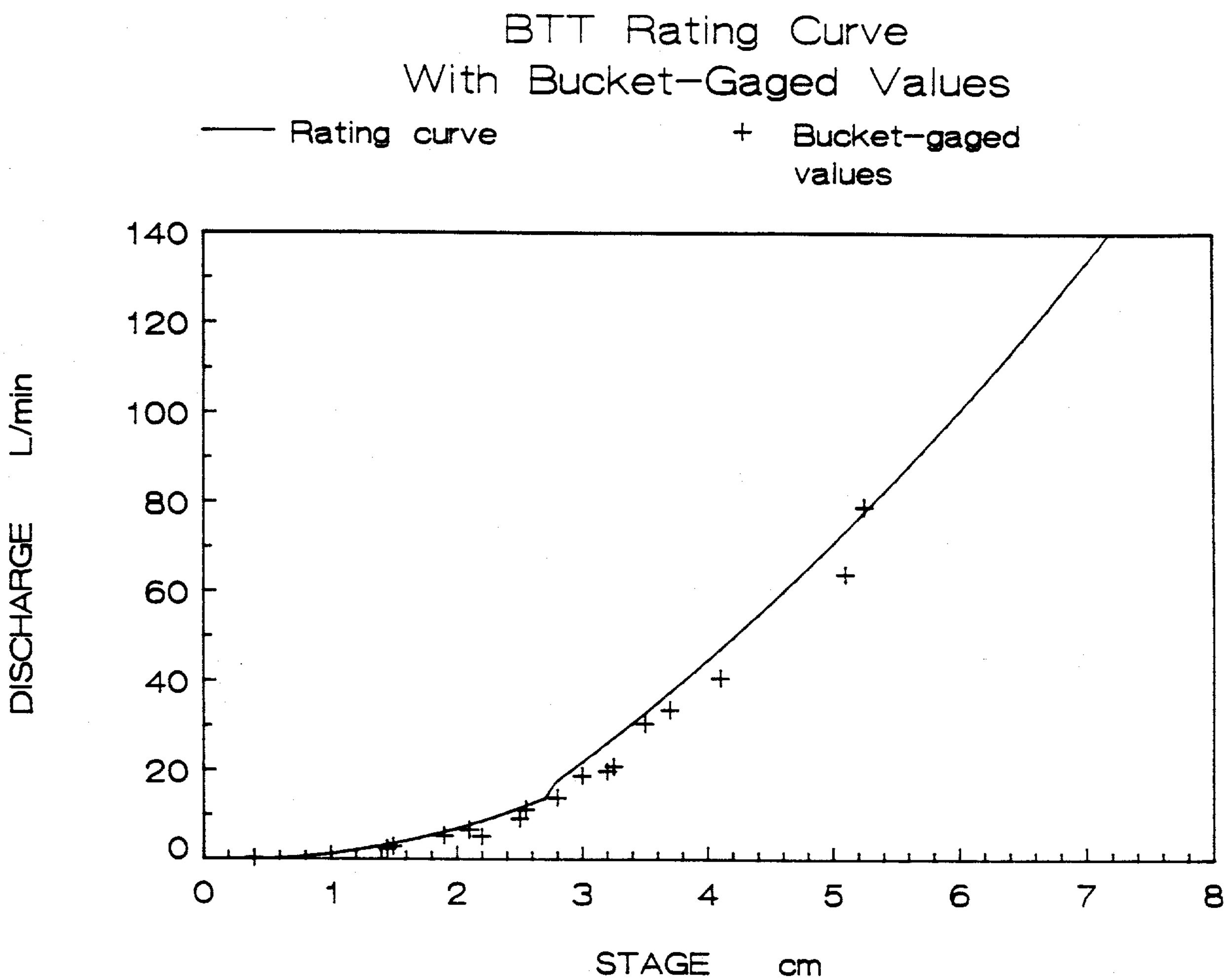

Fig. 9. BTT rating curves, showing bucket-gaged determined discharge values.

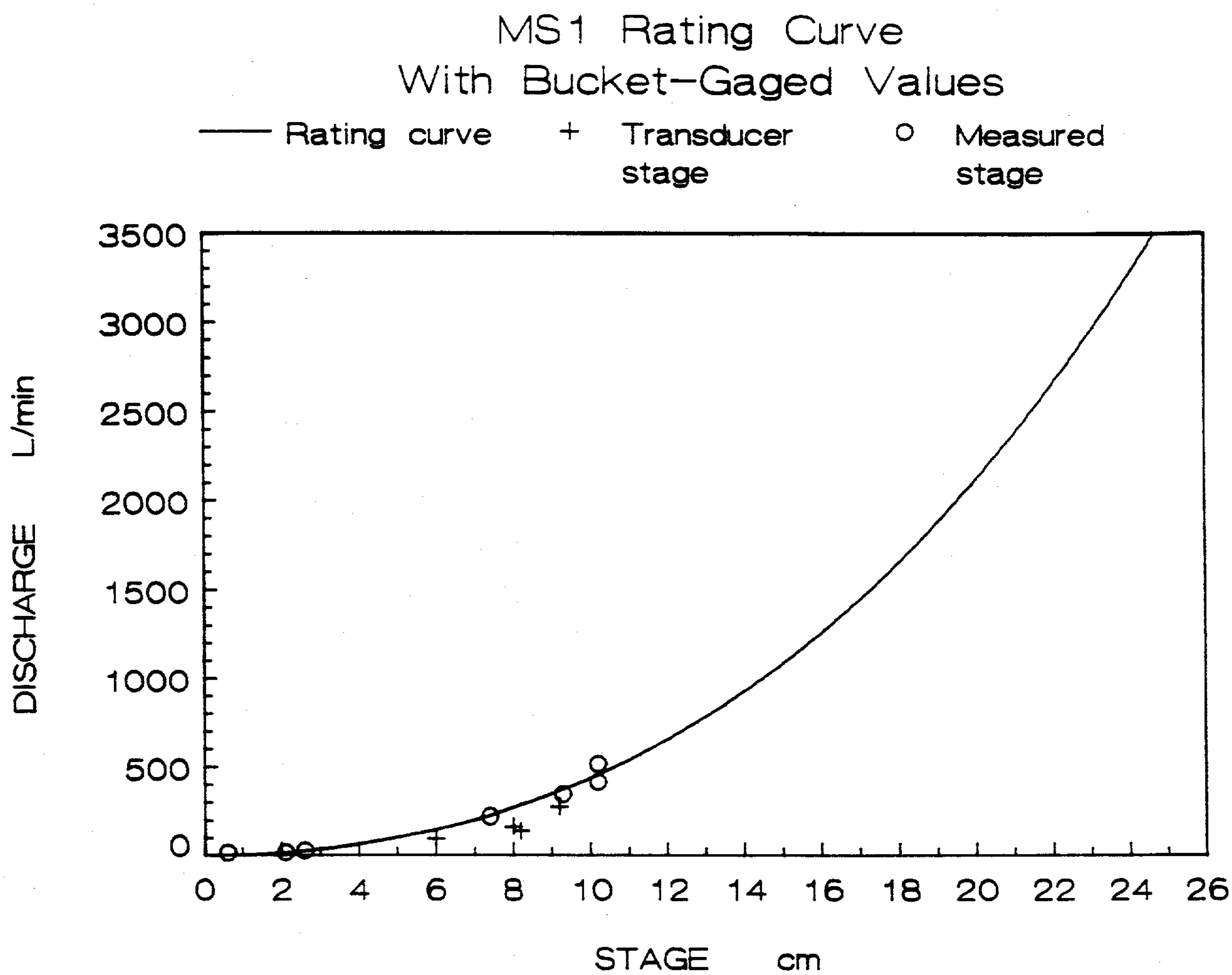

Fig. 10. MS1 rating curve, showing bucket-gaged determined discharge values vs. stage measured both manually and by transducer and data logging equipment.

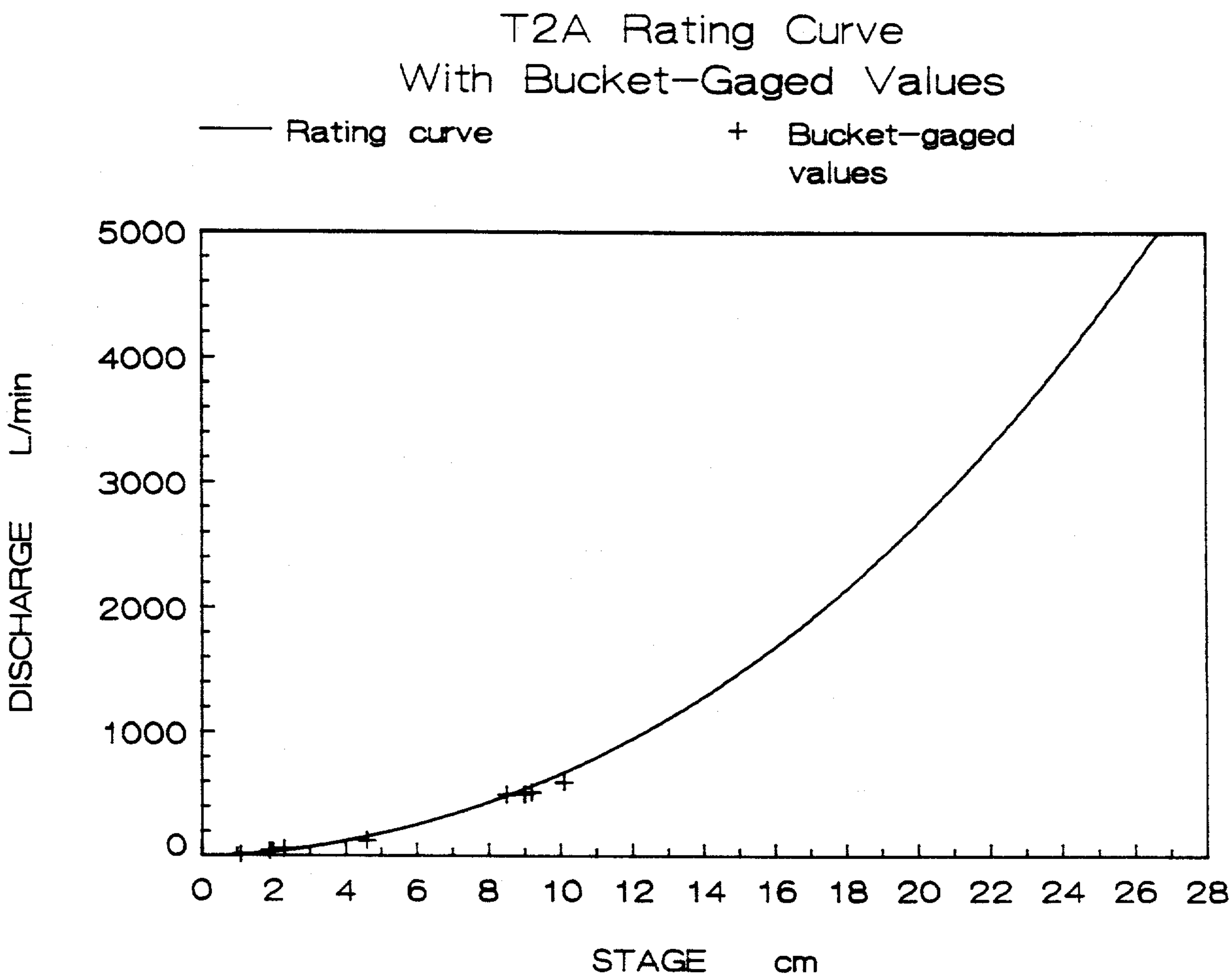

Fig. 11. T2A rating curve, showing bucket-gaged values.

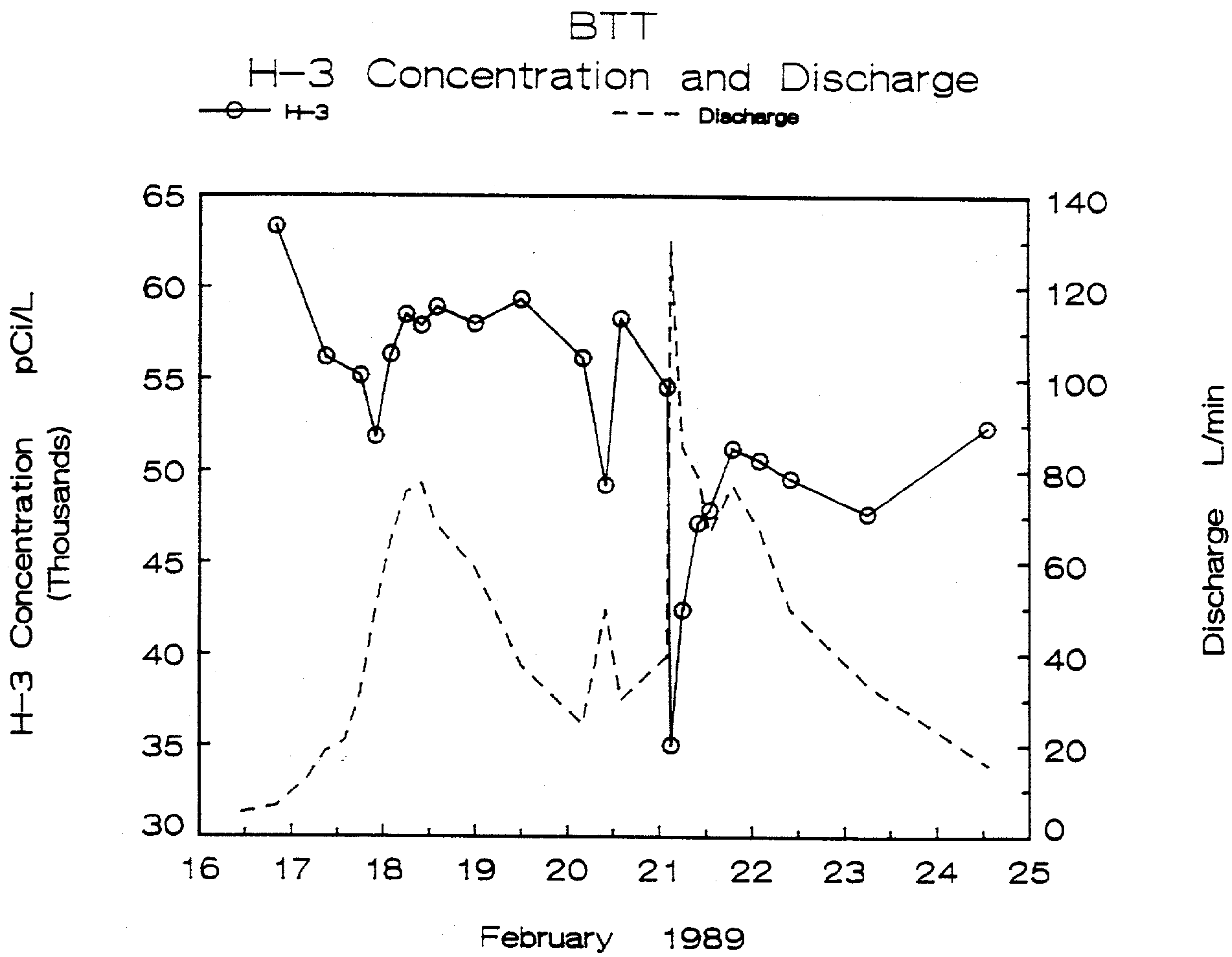

Fig. 12. Tritium concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the February rainstorm events.

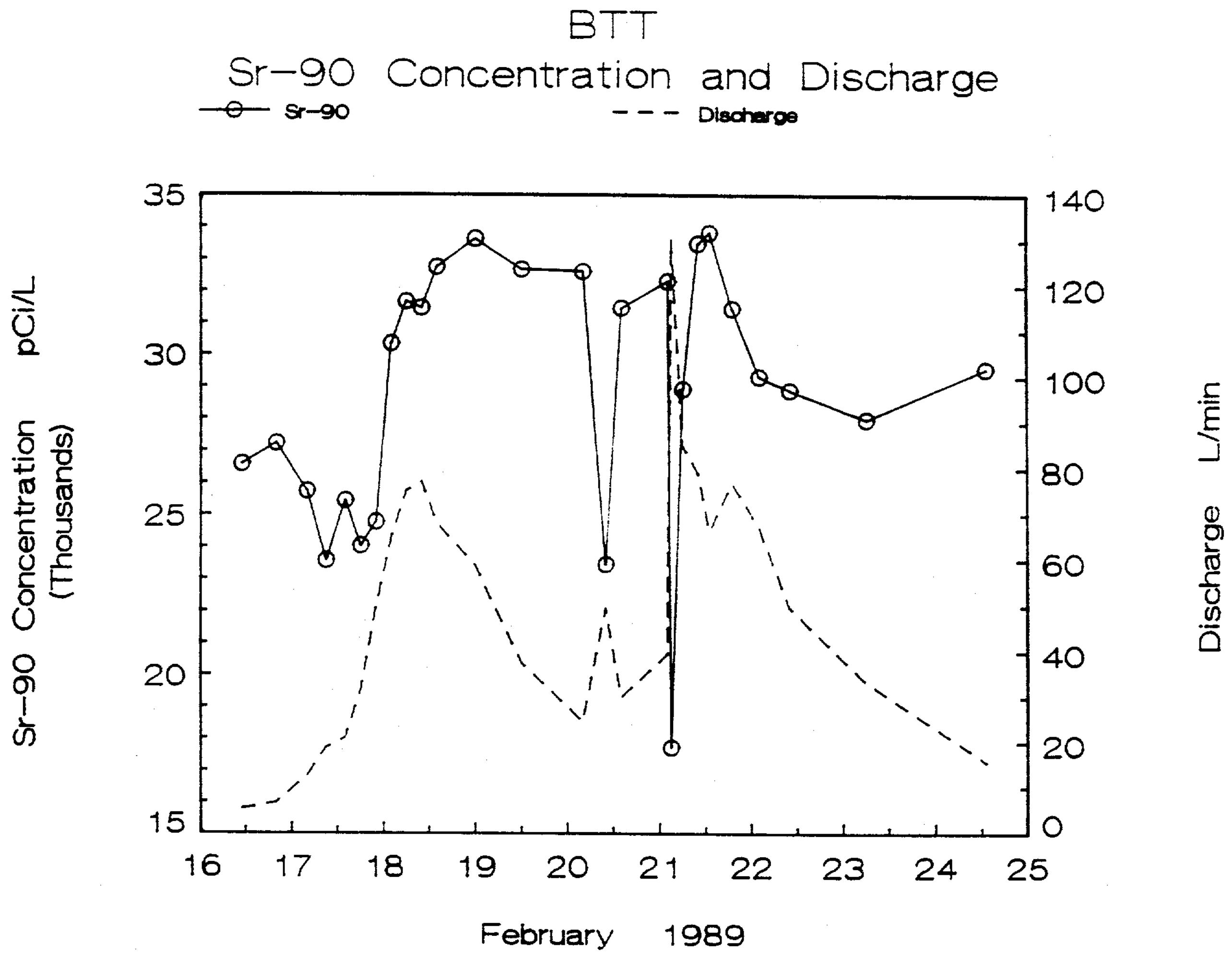

Fig. 13. Strontium-90 concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the February rainstorm events.

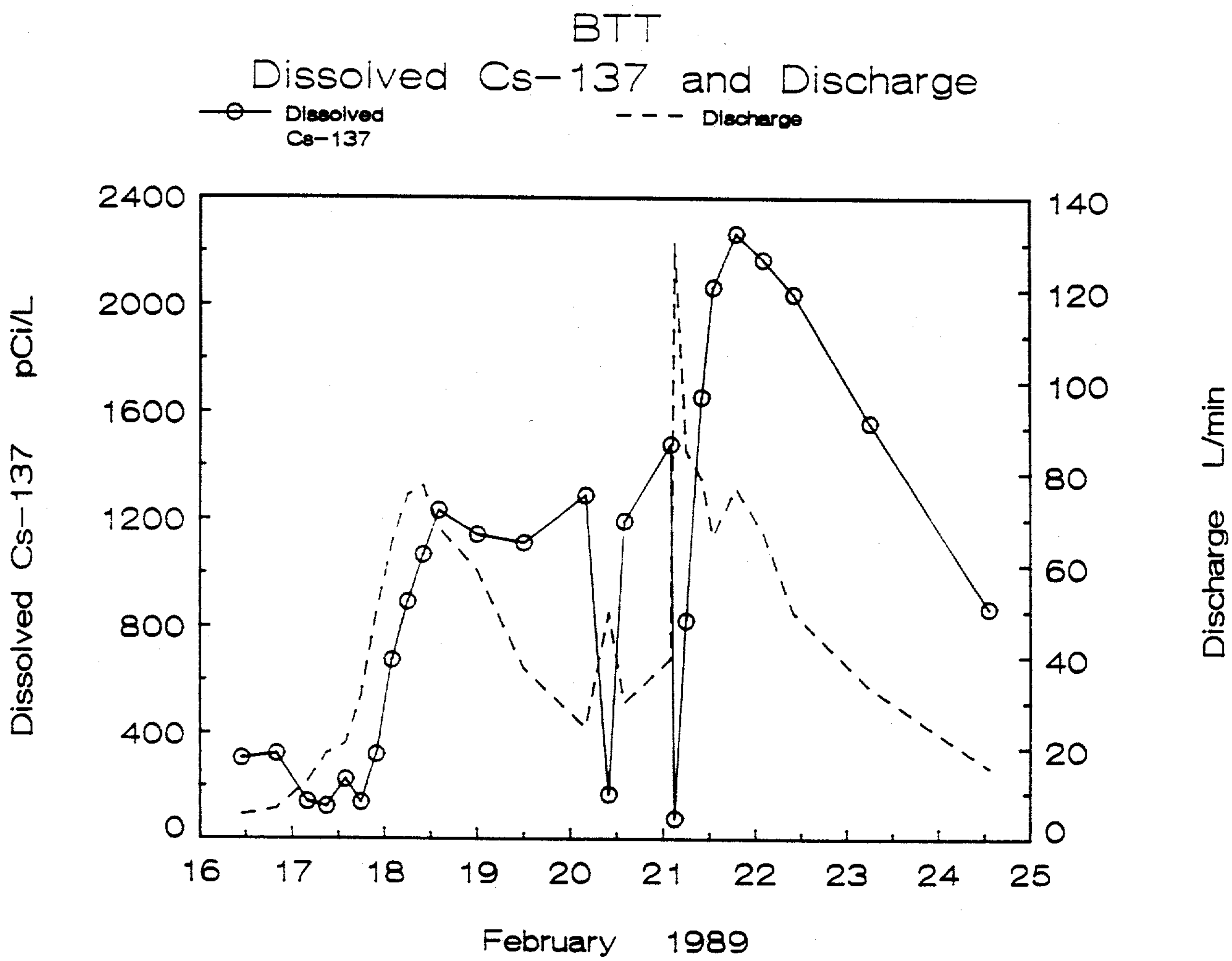

Fig. 14. Dissolved cesium-137 concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the February rainstorm events.

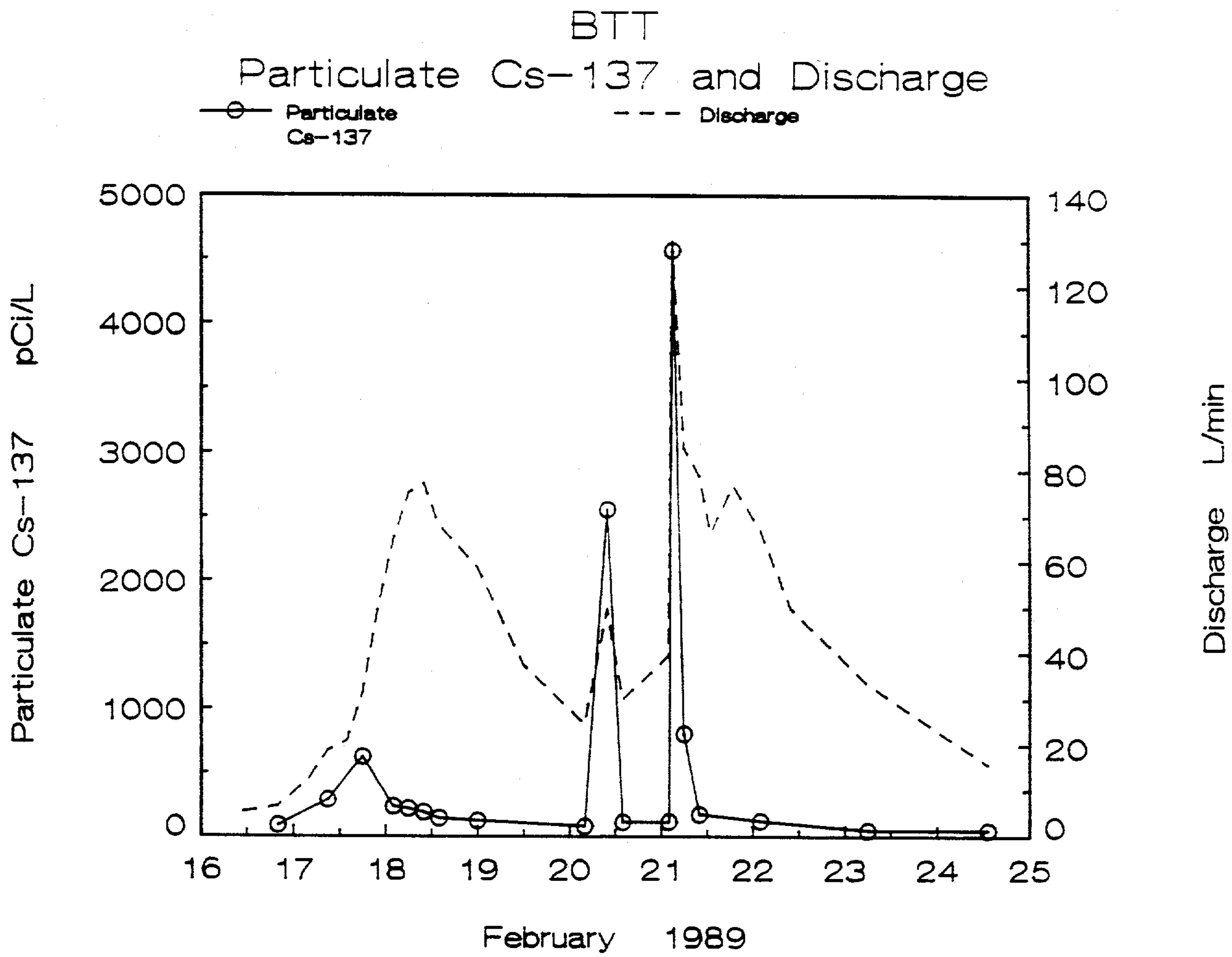

Fig. 15. Particulate-sorbed cesium-137 concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the February rainstorm events.

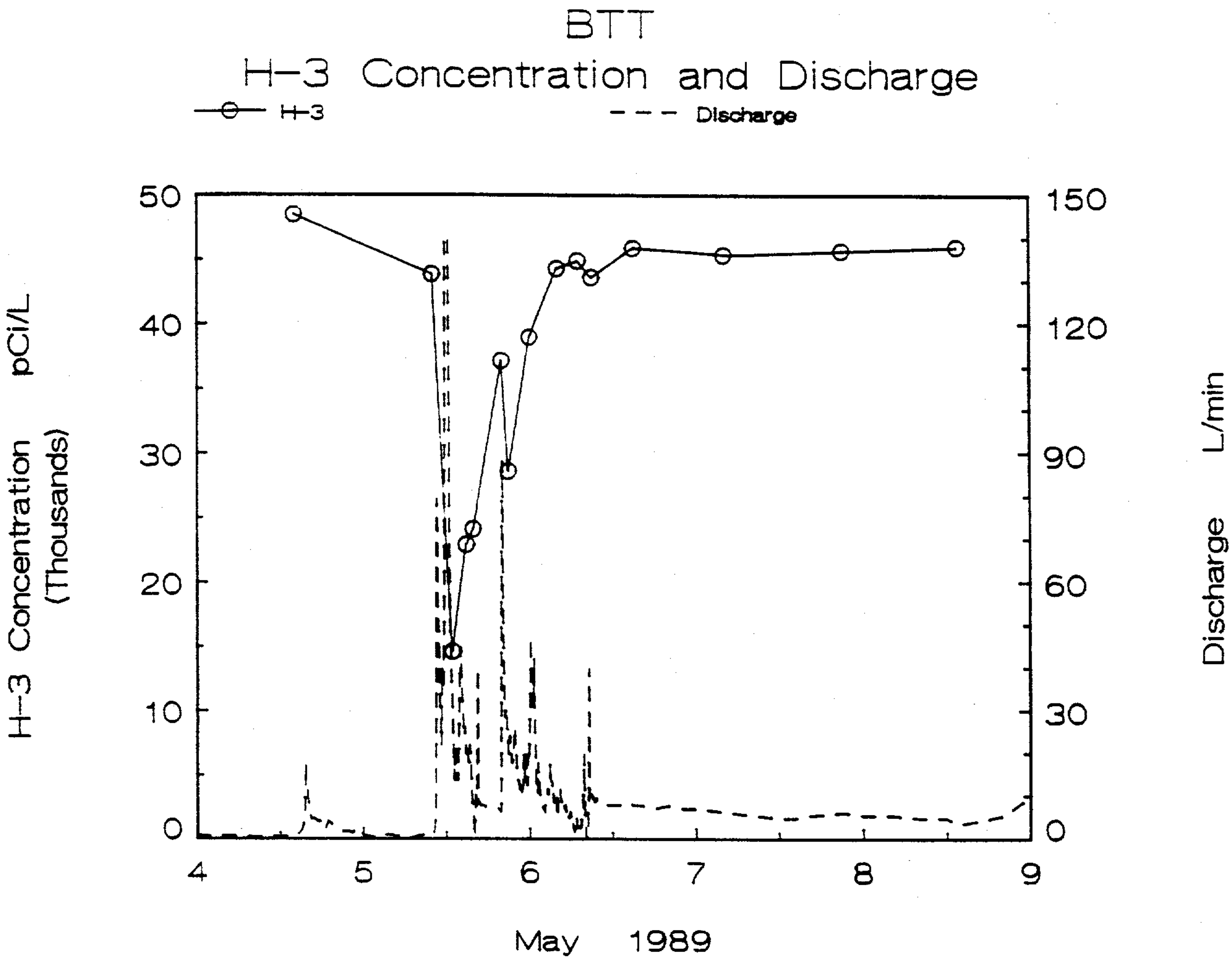

Fig. 16. Tritium concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the May rainstorm event.

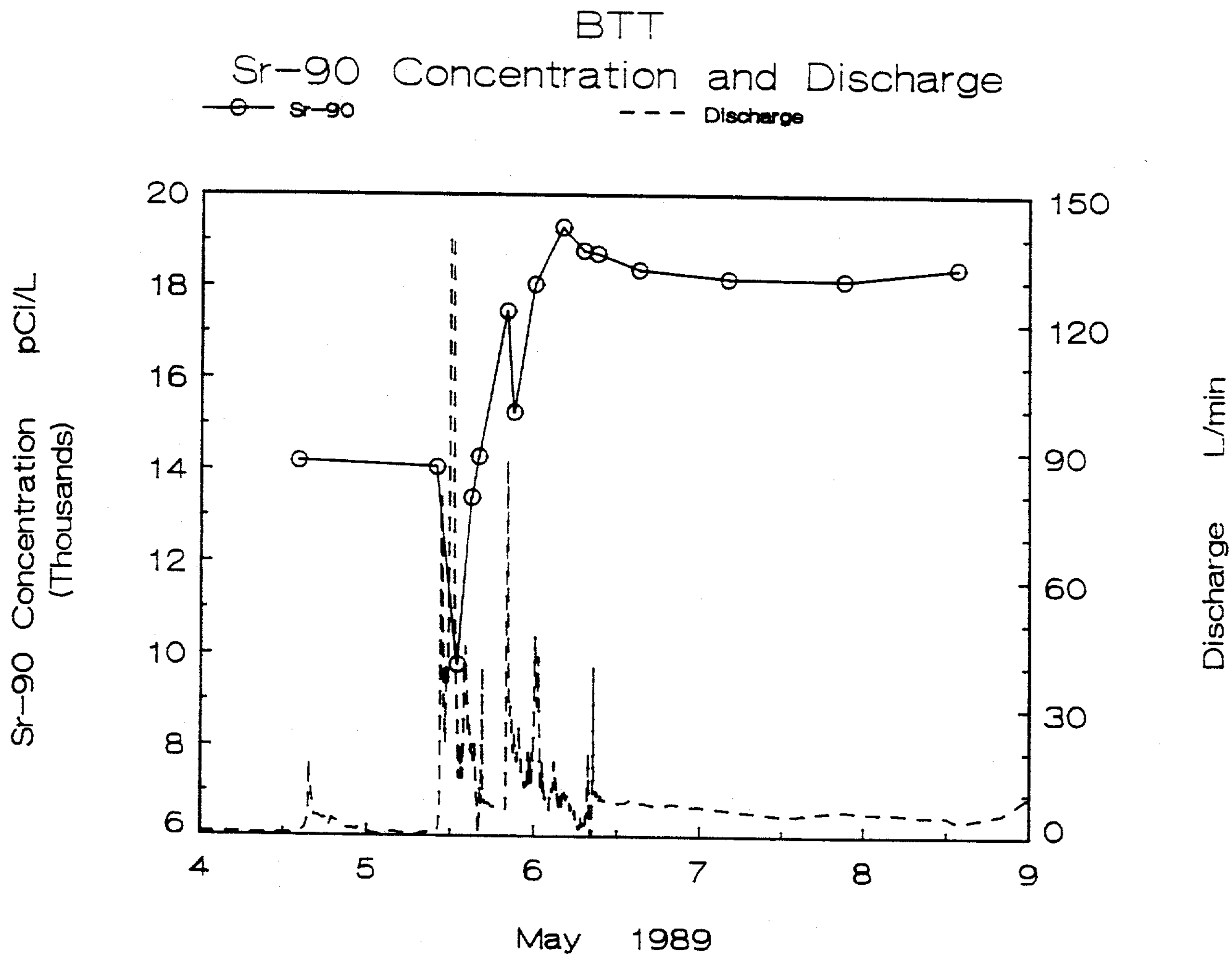

Fig. 17. Strontium-90 concentrations and discharge at BTT, the bathtubbing trench area in SWSA 4, during the May rainstorm event.

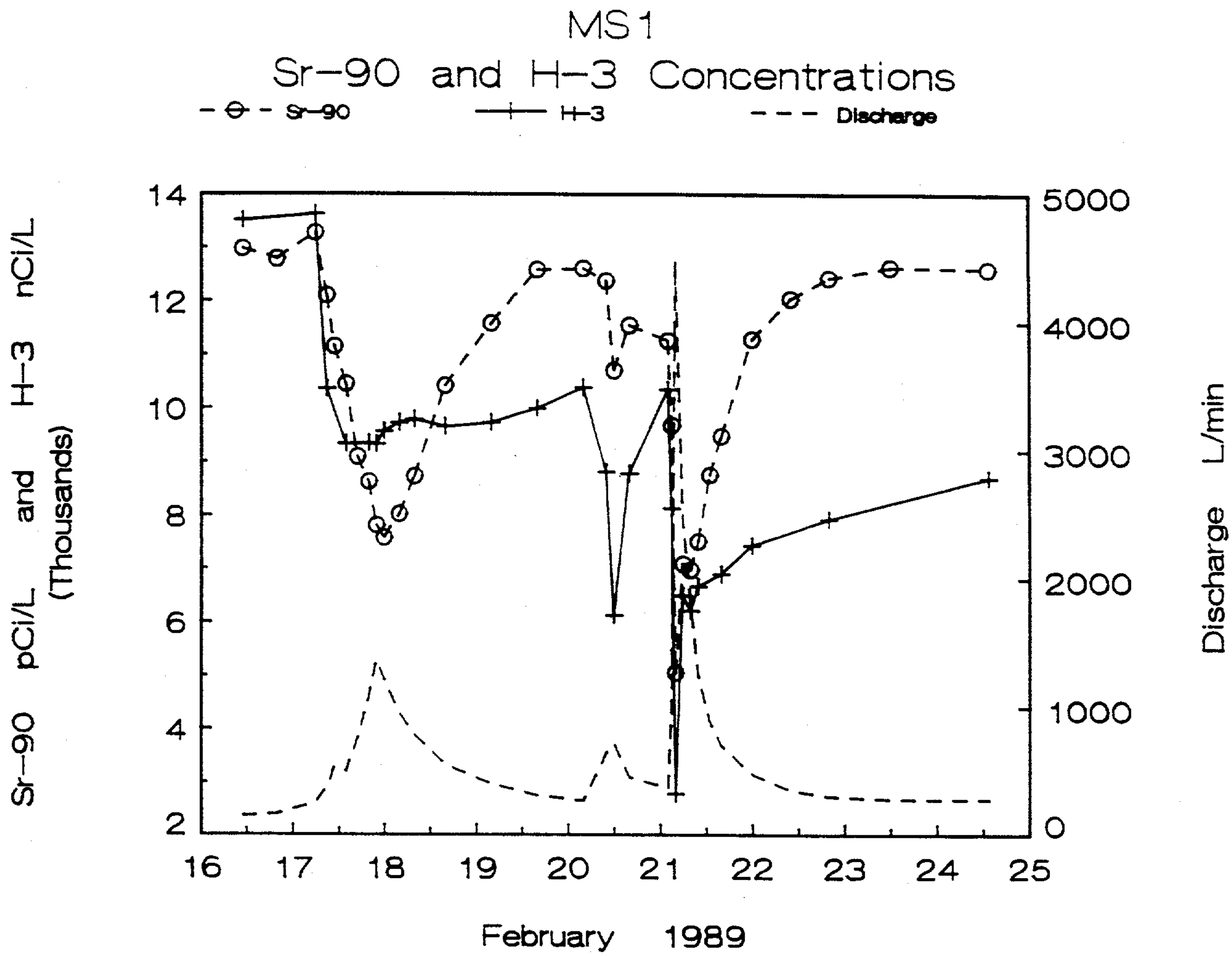

Fig. 18. Strontium-90 and tritium concentrations and discharge of the SWSA 4 tributary at MS1 during the February rainstorm events.

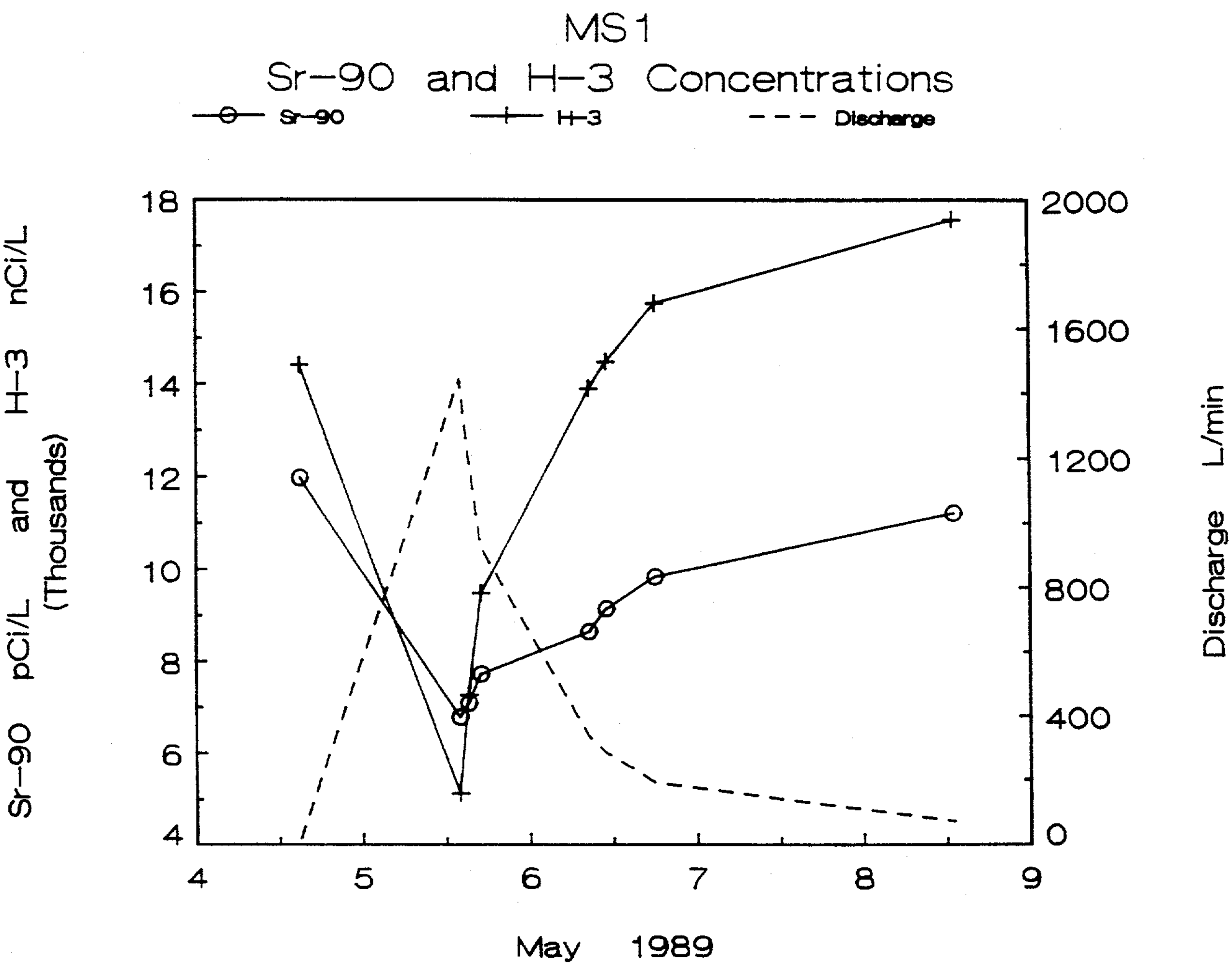

Fig. 19. Strontium-90 and tritium concentrations and discharge of the SWSA 4 tributary at MS1 during the May rainstorm event.

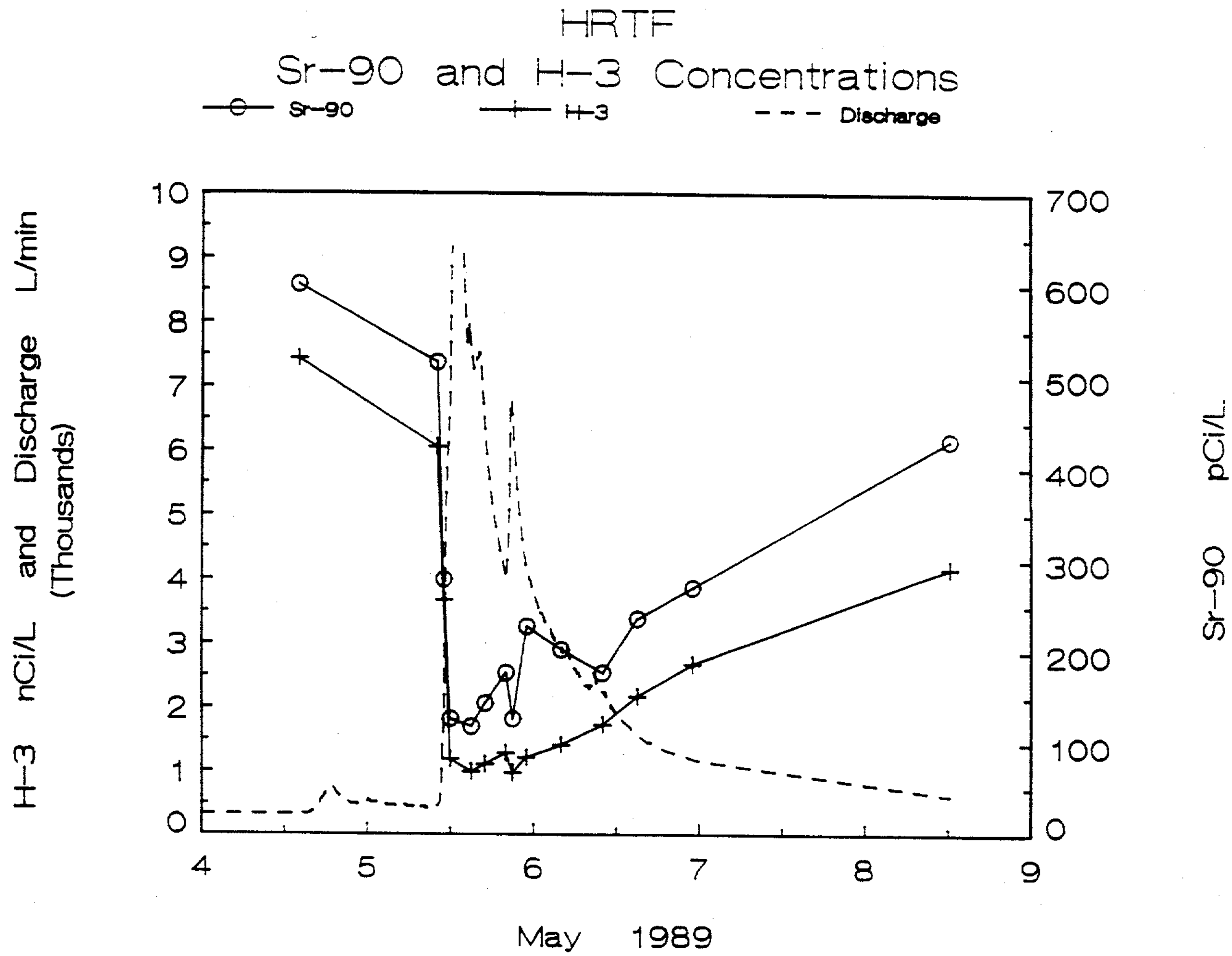

Fig. 20. Strontium-90 and tritium concentrations and discharge of the Melton Branch tributary at HRTF during the May rainstorm event.

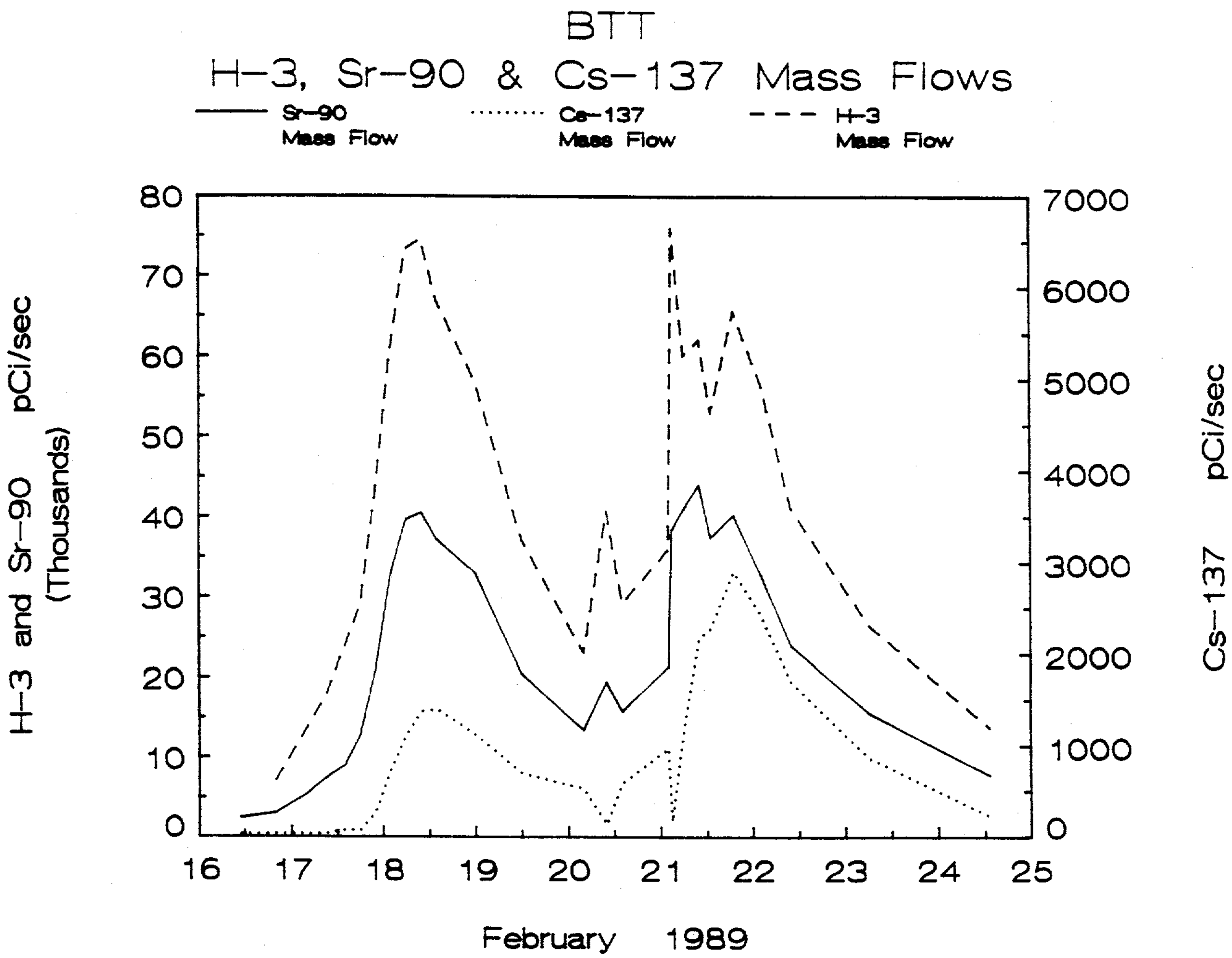

Fig. 21. Tritium, strontium-90 and dissolved cesium-137 mass flows at BTT during the February rainstorm events.

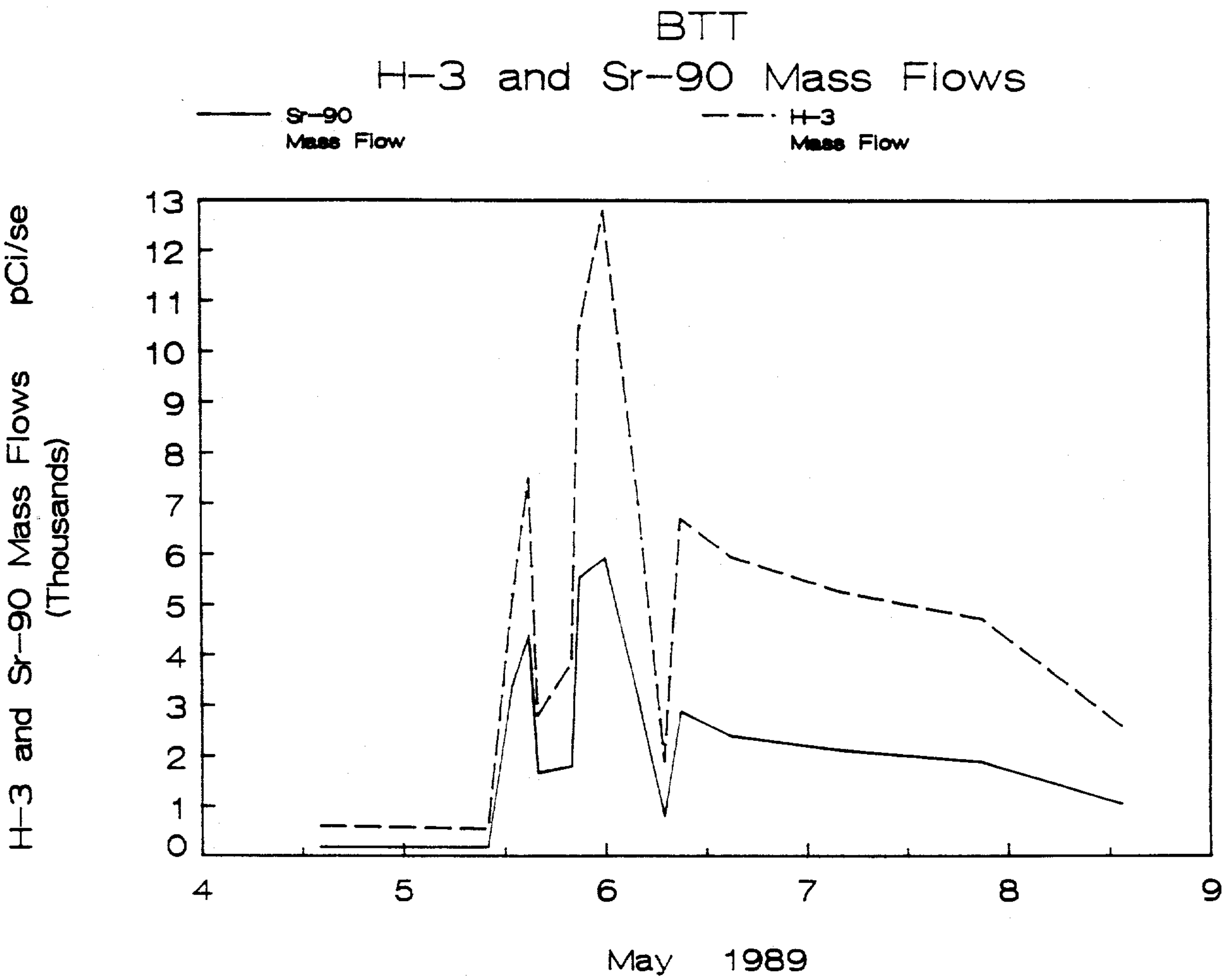

Fig. 22. Tritium and strontium-90 mass flows at BTT during the May rainstorm event.

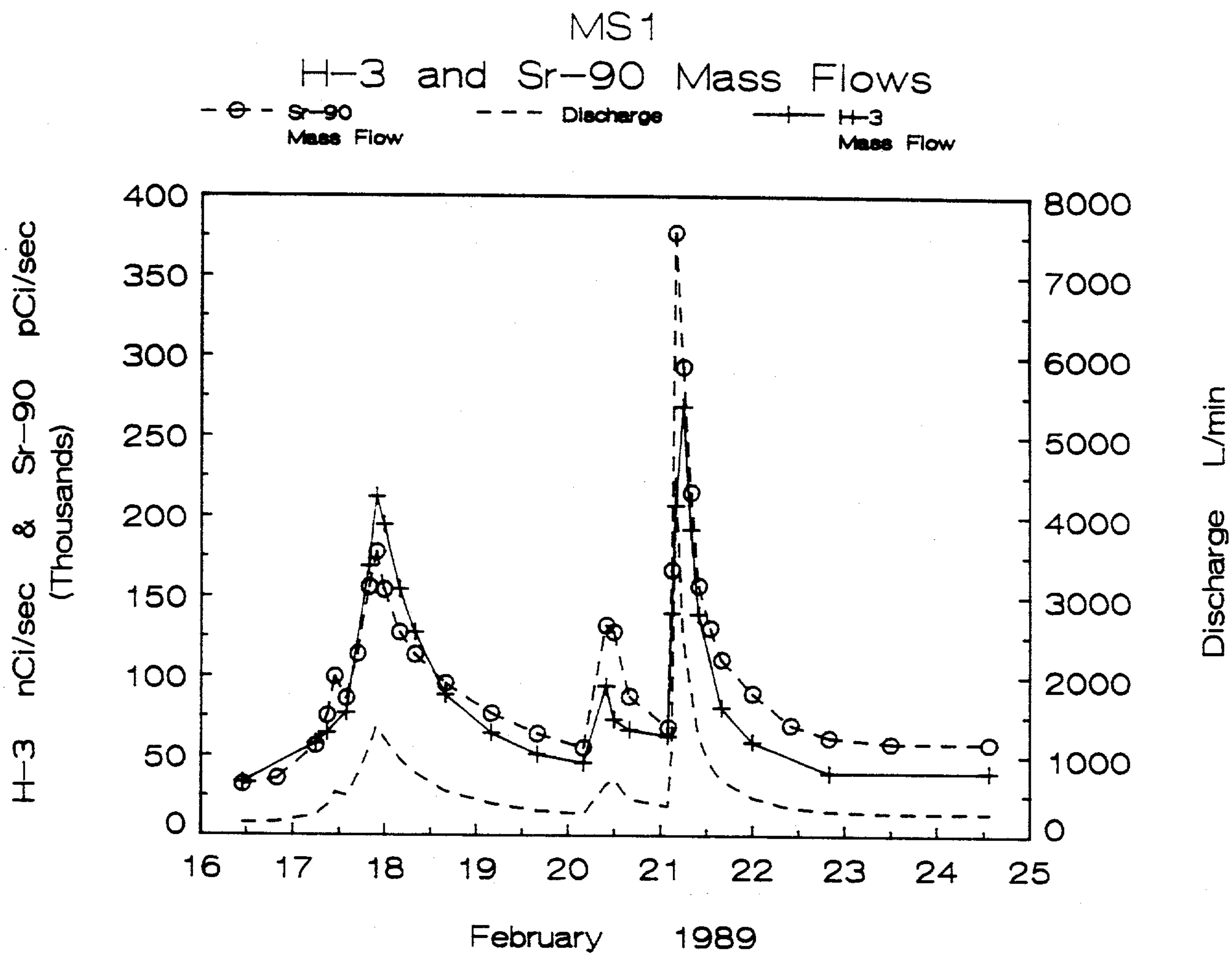

Fig. 23. Tritium and strontium-90 mass flows and discharge at MS1 during the February rainstorm events.

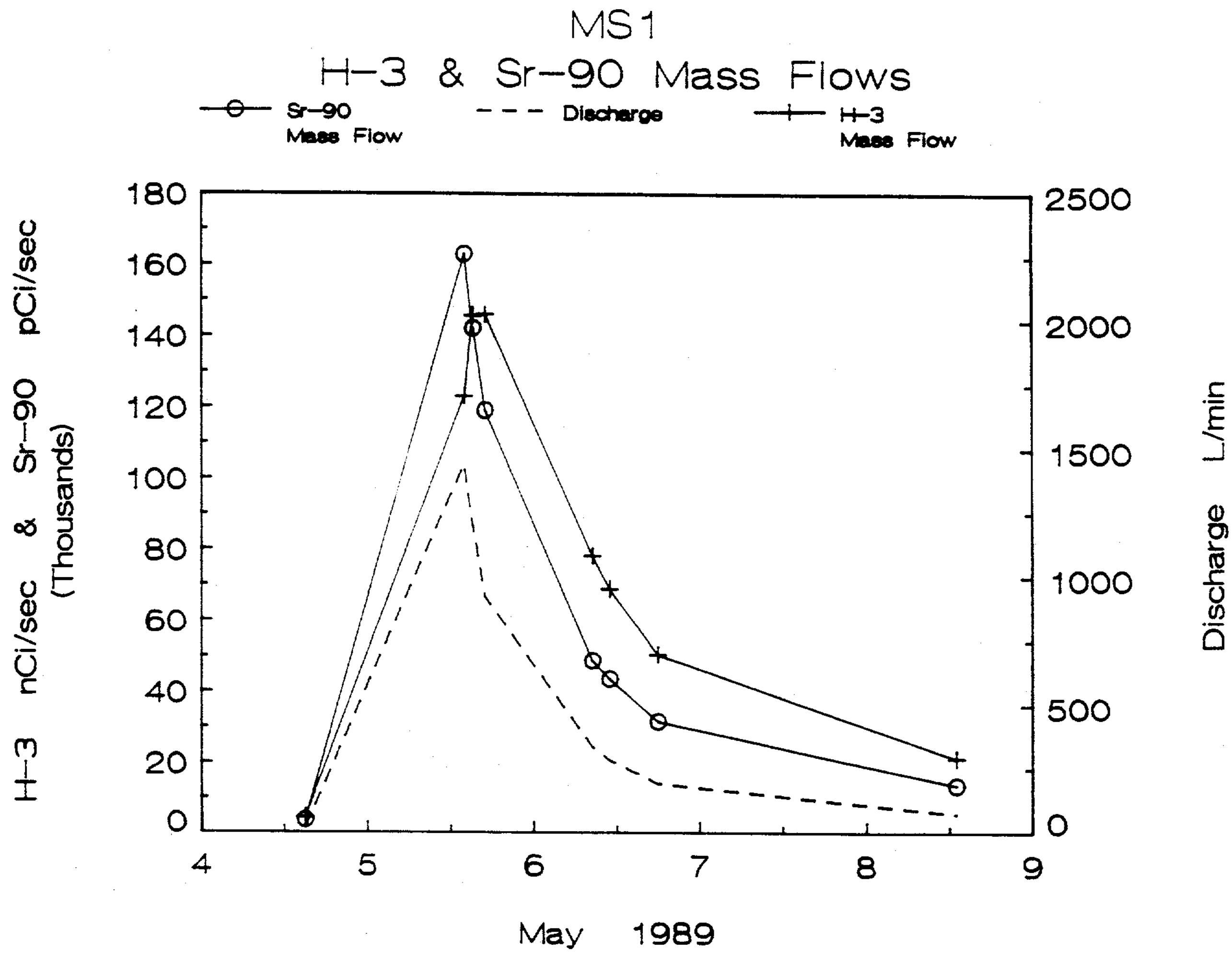

Fig. 24. Tritium and strontium-90 mass flows and discharge at MS1 during the May rainstorm event.

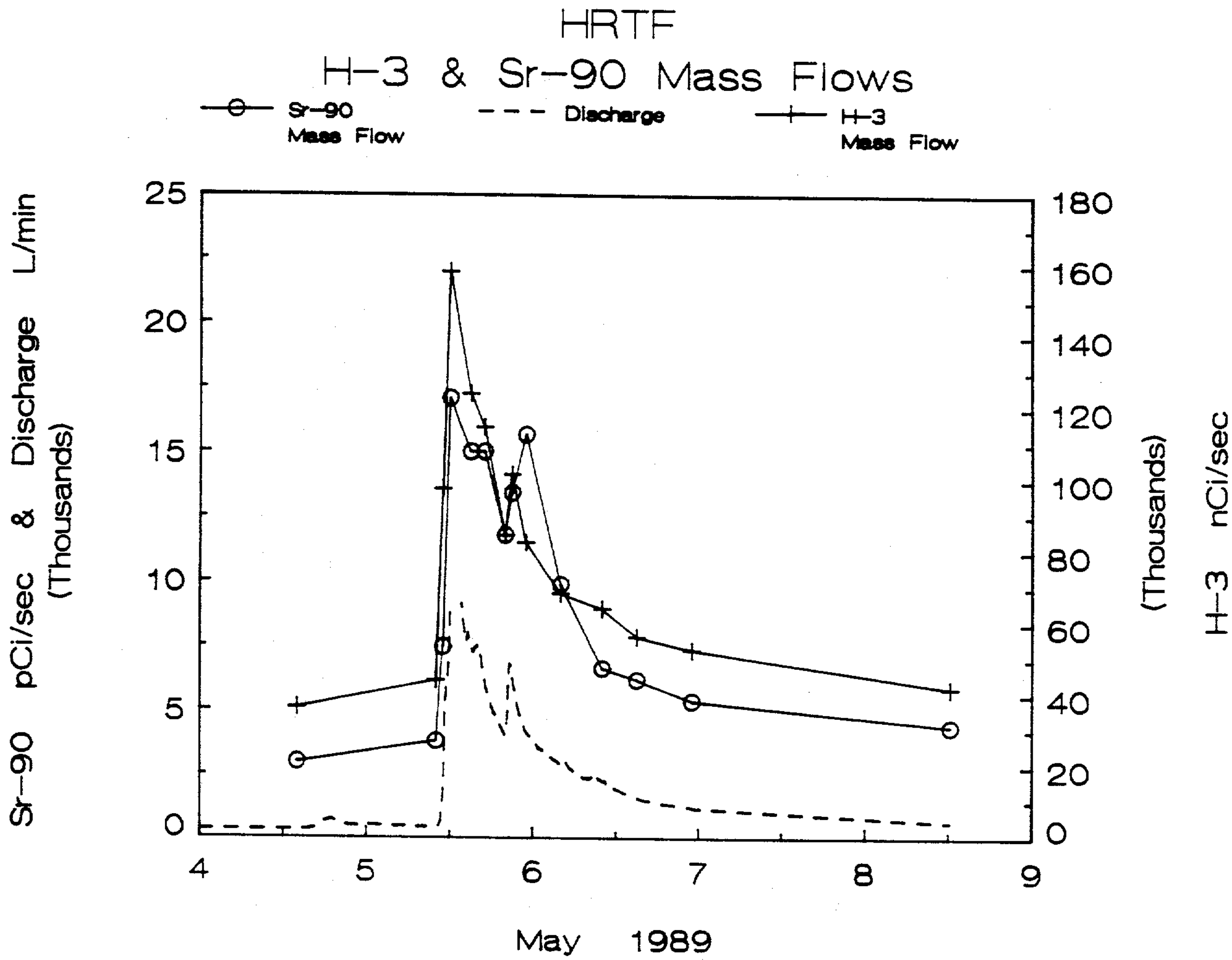

Fig. 25. Tritium and strontium-90 mass flows and discharge at HRTF during the May rainstorm event.

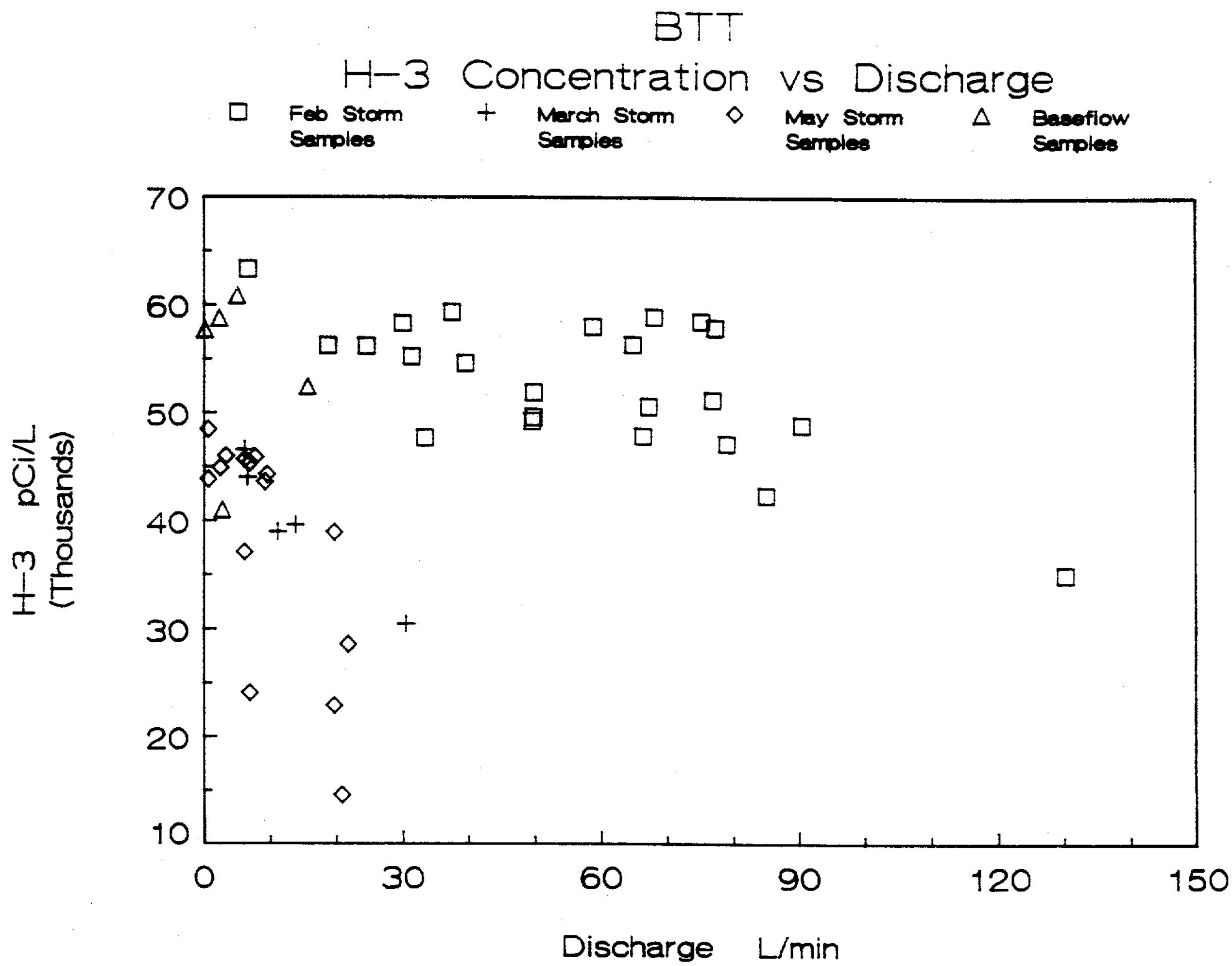

Fig. 26. Relationship between tritium concentration and discharge at the bathtubbing trench area in SWSA 4.

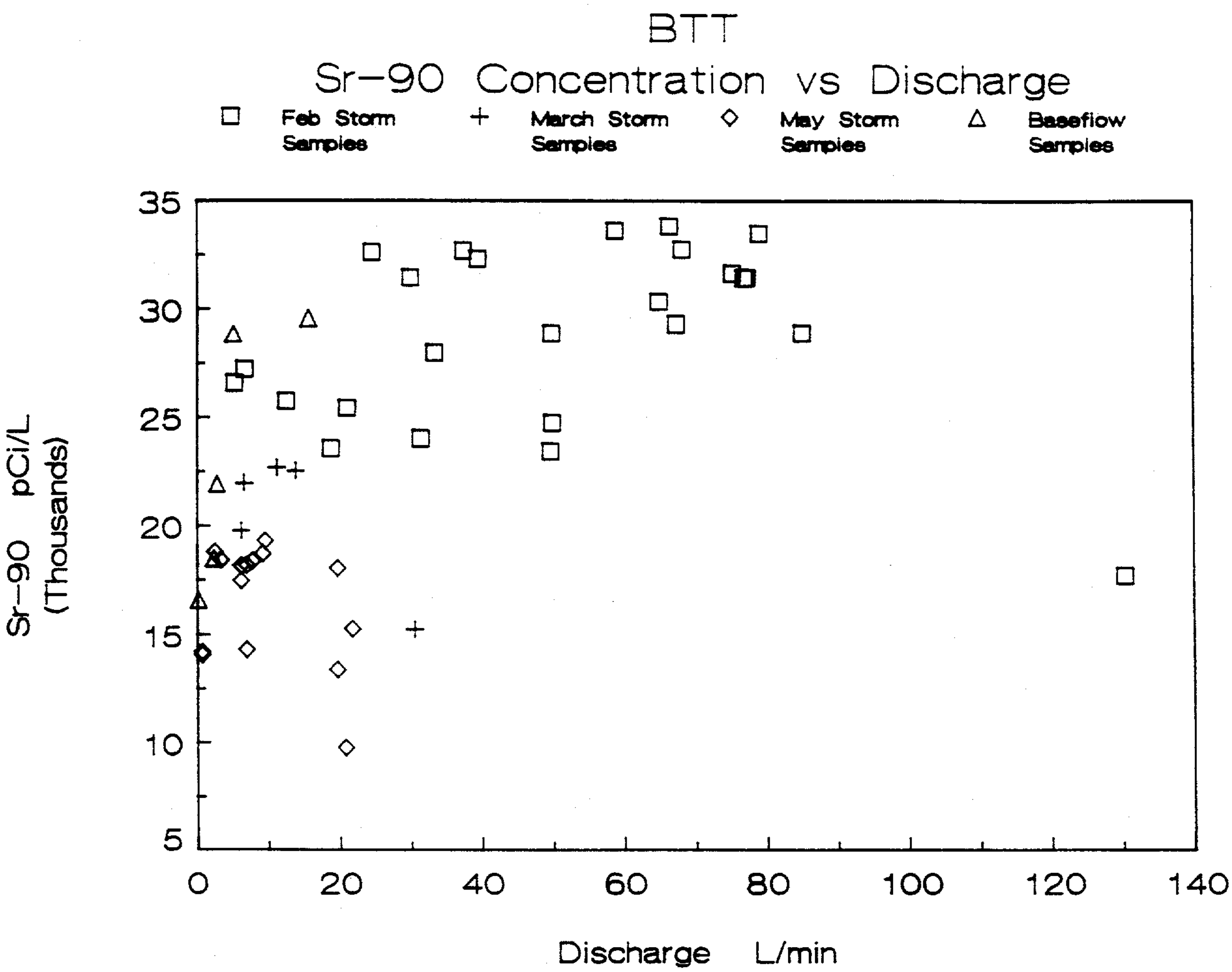

Fig. 27. Relationship between strontium-90 concentration and discharge at the bathtubbing trench area in SWSA 4.

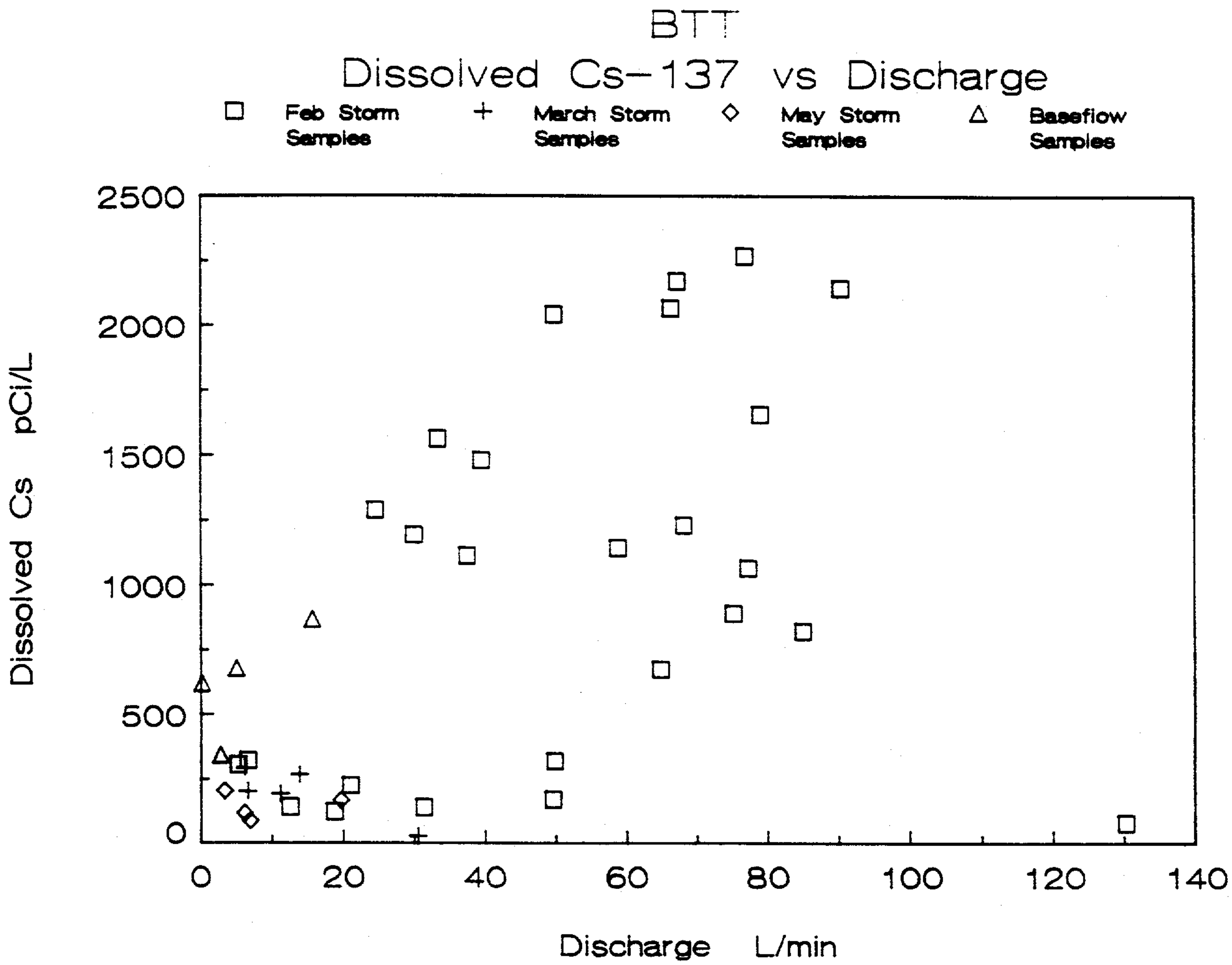

Fig. 28. Relationship between dissolved cesium-137 and discharge at the bathtubbing trench area in SWSA 4.

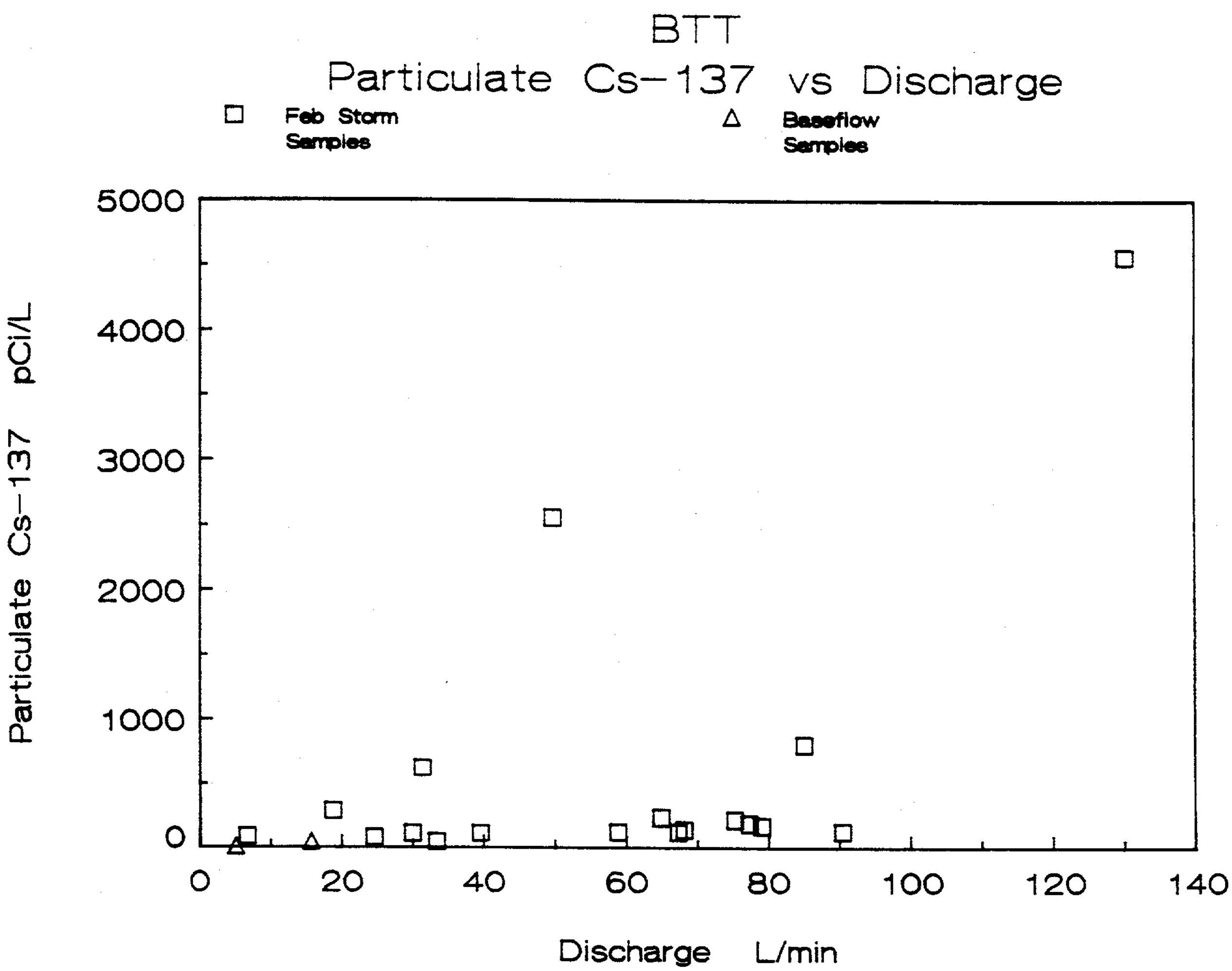

Fig. 29. Relationship between particulate-sorbed cesium-137 and discharge at the bathtubbing trench area in SWSA 4.

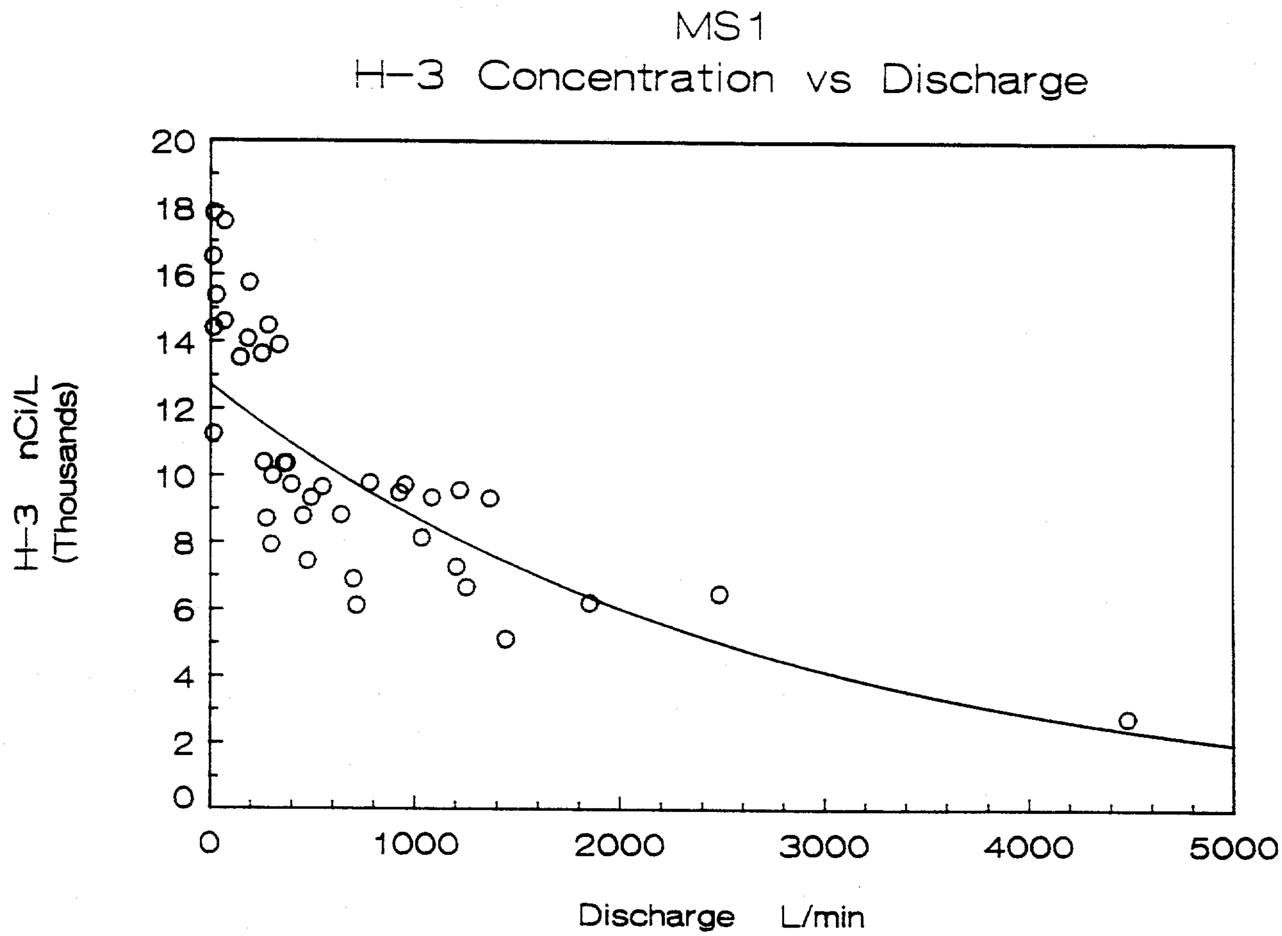

Fig. 30. Relationship between tritium concentration and discharge in the SWSA 4 tributary at MS1.

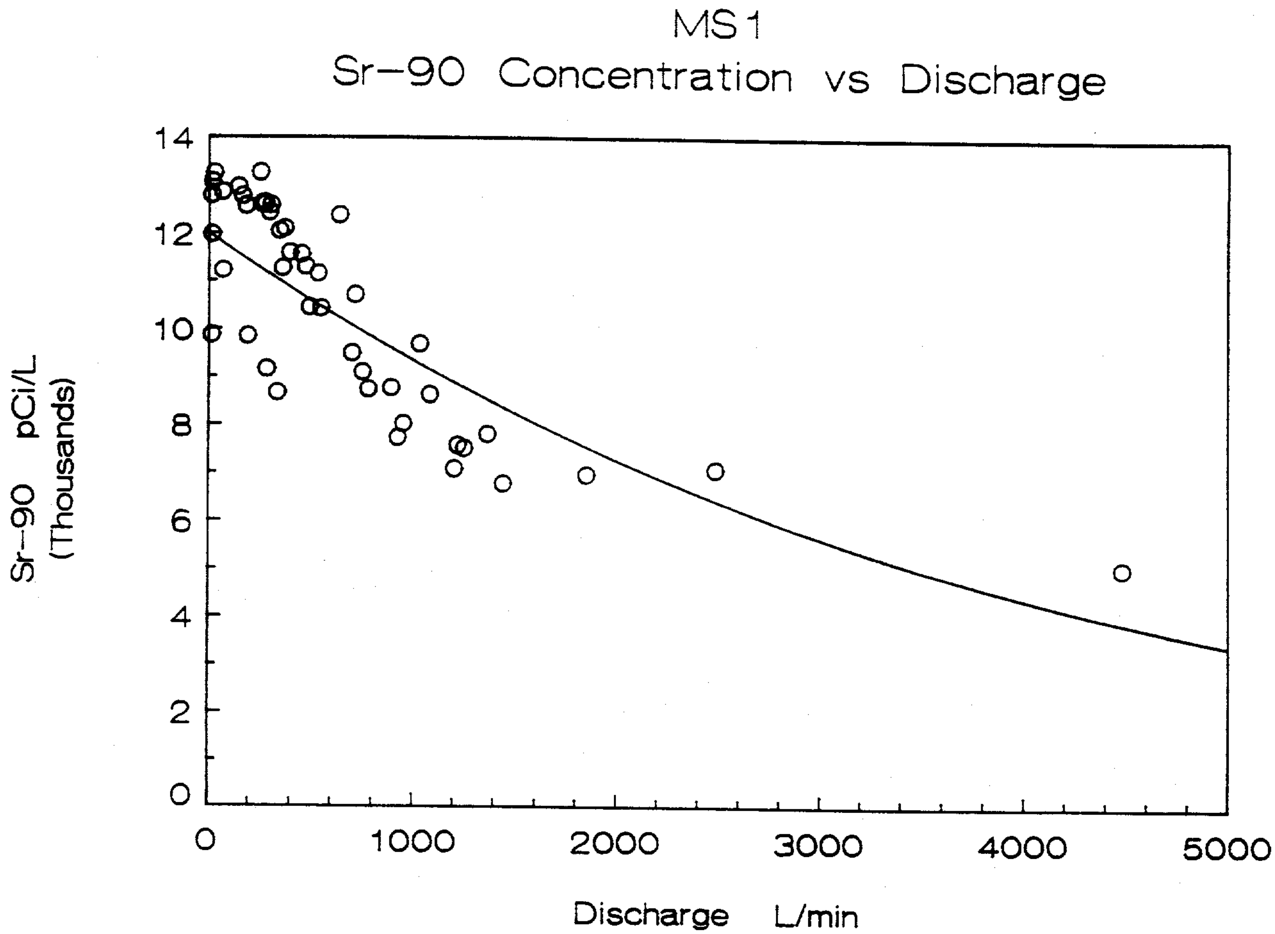

Fig. 31. Relationship between strontium-90 concentration and discharge in the SWSA 4 tributary at MS1.

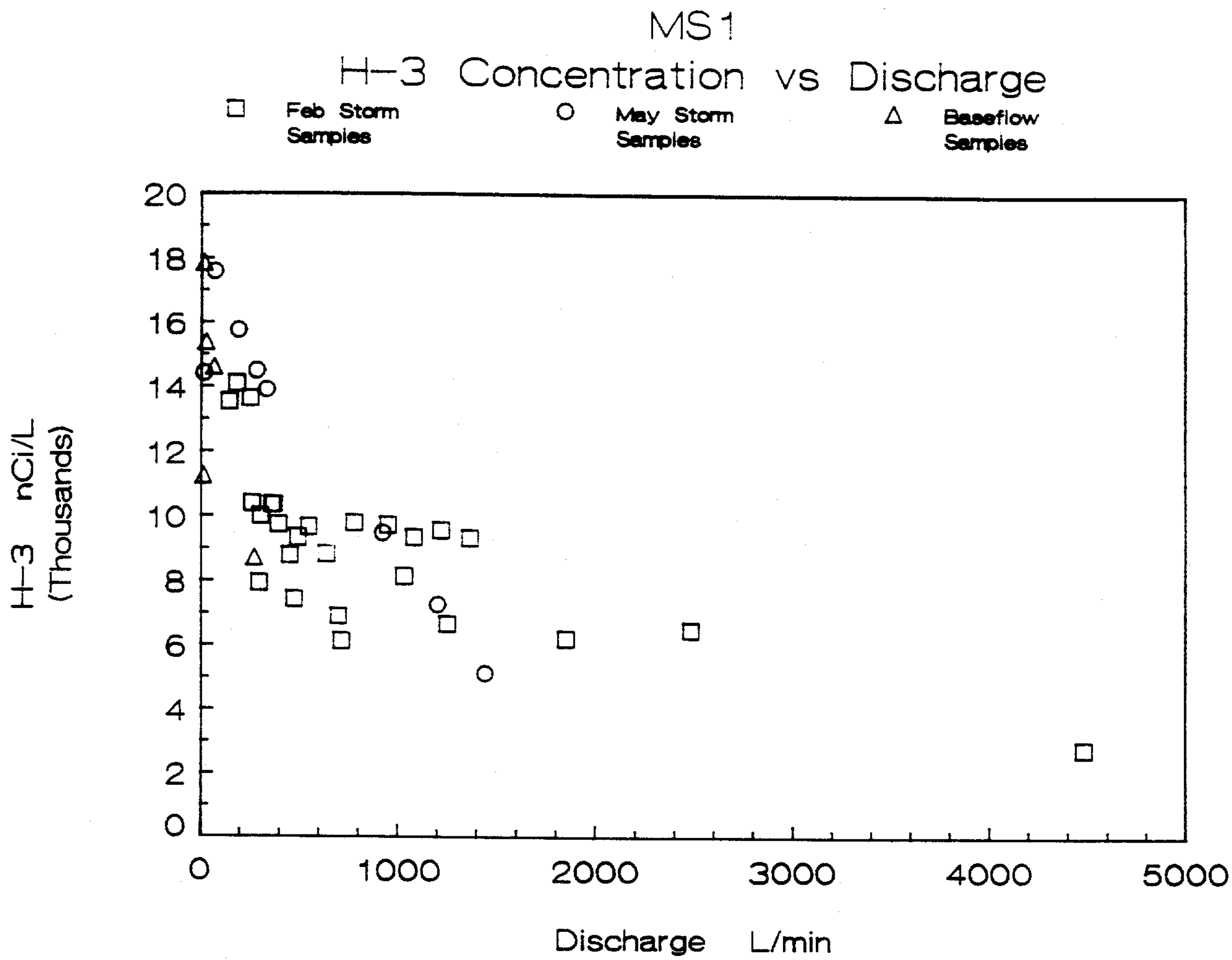

Fig. 32. Relationship between tritium concentration and discharge in the SWSA 4 tributary at MS1 for different sampling periods.

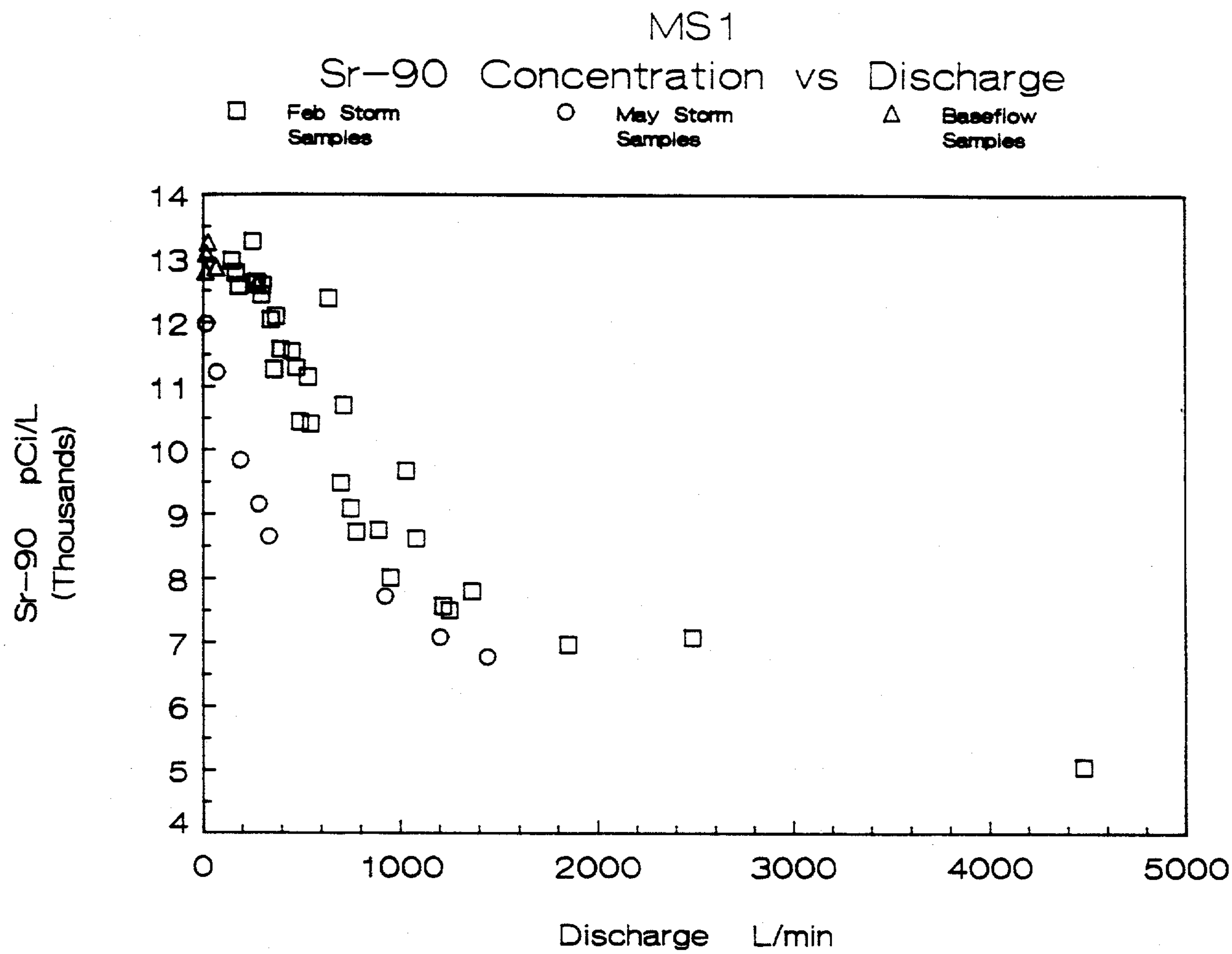

Fig. 33. Relationship between strontium-90 concentration and discharge in the SWSA 4 tributary at MS1 for different sampling periods.

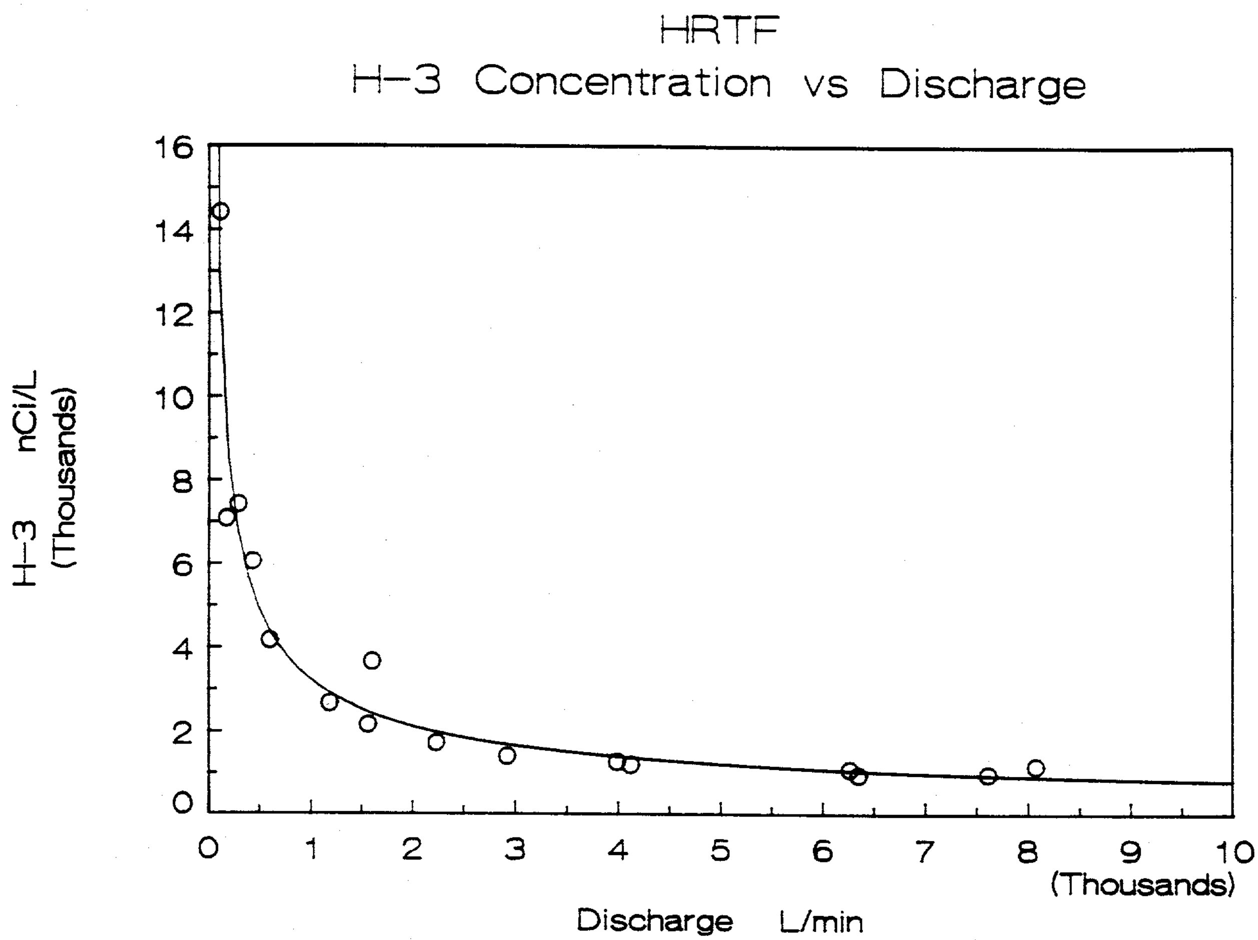

Fig. 34. Relationship between tritium concentration and discharge in the Melton Branch tributary at HRTF.

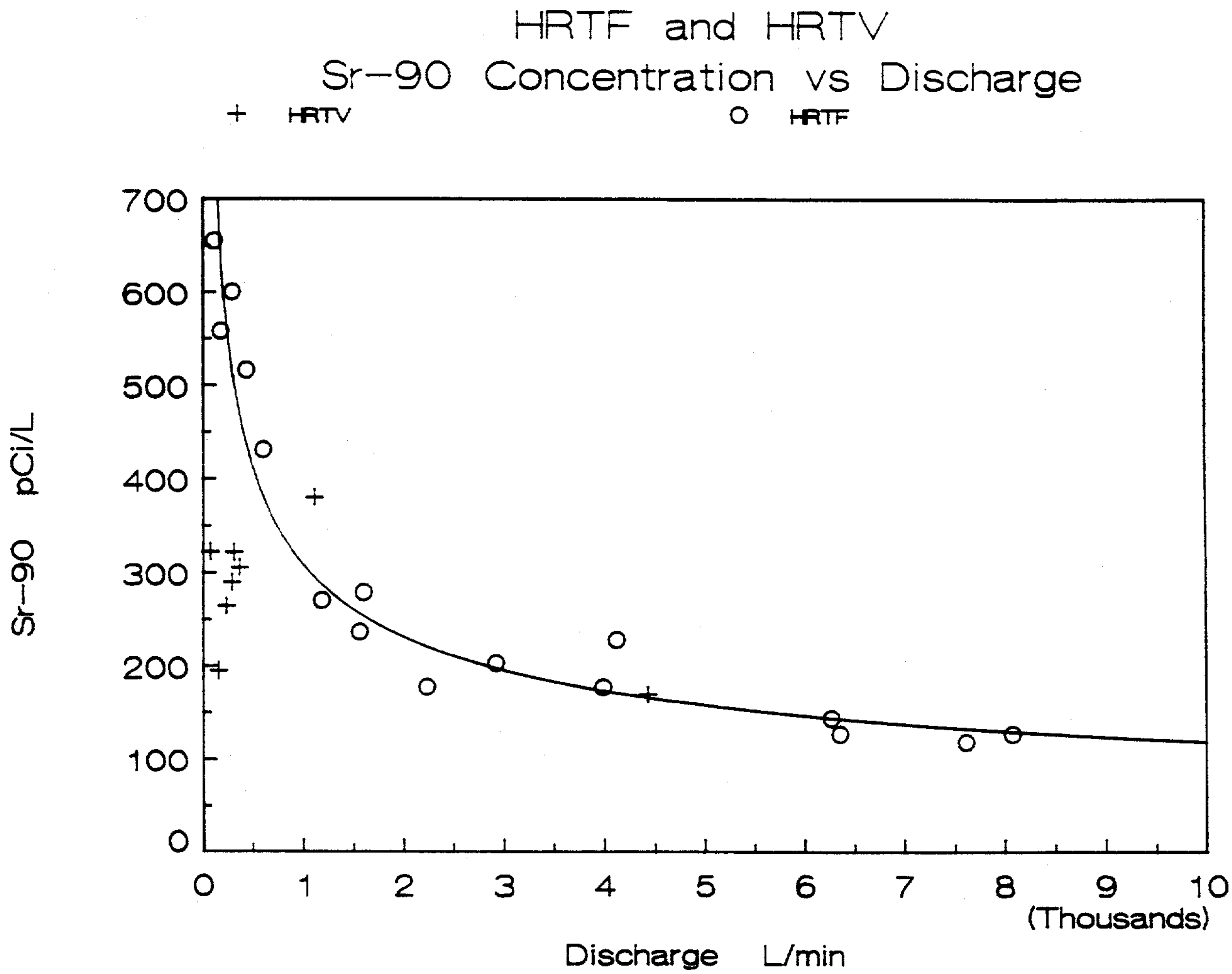

Fig. 35. Relationships between strontium-90 concentration and discharge in the Melton Branch tributary at HRTF and HRTV.

APPENDIX

Baseflow and Storm Sampling Results for BTT

LOCATION	DATE	TIME	DISCHARGE L/min	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
BTT	01/23/89	15:45	5.12	28837	1.86	60.81	0.69
BTT	02/13/89	16:00		28323	1.85	67.29	0.66
BTT	02/14/89	11:00					
BTT	02/14/89	13:00					
BTT	02/14/89	20:00					
BTT	02/15/89	12:00		27043	1.80		
BTT	02/16/89	07:00		26925	1.80		
BTT	02/16/89	11:00	5.32	26554	1.79		
BTT	02/16/89	20:00	6.72	27211	1.81	63.28	0.69
BTT	02/17/89	04:00	12.54	25720	1.76		
BTT	02/17/89	09:00	18.78	23556	1.68	56.18	0.73
BTT	02/17/89	14:00	21.06	25426	1.75		
BTT	02/17/89	18:00	31.38	24019	1.70	55.17	0.74
BTT	02/17/89	22:00	49.86	24760	1.73	51.85	0.76
BTT	02/18/89	02:00	64.86	30328	1.91	56.33	0.73
BTT	02/18/89	06:00	75.18	31650	1.95	58.49	0.71
BTT	02/18/89	10:00	77.28	31448	1.94	57.88	0.72
BTT	02/18/89	14:00	68.1	32737	1.98	58.90	0.71
BTT	02/19/89	00:00	58.8	33613	2.01	57.98	0.71
BTT	02/19/89	12:00	37.5	32661	1.98	59.33	0.7
BTT	02/20/89	04:00	24.6	32594	1.98	56.13	0.73
BTT	02/20/89	10:00	49.62	23438	1.68	49.21	0.79
BTT	02/20/89	14:00	30	31448	1.94	58.29	0.71
BTT	02/21/89	02:00	39.54	32299	1.97	54.56	0.75
BTT	02/21/89	03:00	130.32	17693	1.46	35.01	0.96
BTT	02/21/89	06:00	95.02	28913	1.86	42.42	0.86
BTT	02/21/89	10:00	78.99	33478	2.00	47.17	0.81
BTT	02/21/89	13:00	66.36	33815	2.01	47.88	0.8
BTT	02/21/89	19:00	76.86	31431	1.94	51.20	0.77
BTT	02/22/89	02:00	67.26	29292	1.88	50.58	0.78
BTT	02/22/89	10:00	49.6	28862	1.86	49.58	0.79
BTT	02/23/89	06:00	33.36	27961	1.83	47.66	0.8
BTT	02/24/89	13:10	15.71	29553	1.88	52.37	0.76

APPENDIX

Baseflow and Storm Sampling Results for BTT (cont)

LOCATION	DATE	TIME	DISCHARGE L/min	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
BTT	03/17/89	09:35	2.87	21906	1.64	40.97	0.75
BTT	03/18/89	06:00					
BTT	03/18/89	10:00					
BTT	03/18/89	11:30	30.52	15224	1.37	30.44	0.89
BTT	03/18/89	12:00					
BTT	03/18/89	13:00					
BTT	03/18/89	14:00	6.63	21964	1.64	44.02	0.73
BTT	03/20/89	10:00	6.19	19745	1.55	46.58	0.7
BTT	03/21/89	09:20	13.84	22529	1.66	39.56	0.77
BTT	03/22/89	10:10	11.18	22662	1.66	38.95	0.77
BTT	04/27/89	13:50	0.24	16545	1.43	57.66	0.72
BTT	05/04/89	14:00	0.74	14176	1.32	48.44	0.68
BTT	05/05/89	10:00	0.74	14052	1.32	43.82	0.72
BTT	05/05/89	13:00	20.82	9761	1.10	14.55	1.37
BTT	05/05/89	15:00	19.68	13388	1.29	22.89	1.04
BTT	05/05/89	16:00	6.96	14284	1.33	24.08	1.01
BTT	05/05/89	20:00	6.19	17455	1.47	37.11	0.79
BTT	05/05/89	21:00	21.78	15255	1.37	28.57	0.92
BTT	05/06/89	00:00	19.69	18044	1.49	38.93	0.77
BTT	05/06/89	04:00	9.54	19289	1.54	44.28	0.71
BTT	05/06/89	07:00	2.53	18775	1.52	44.88	0.71
BTT	05/06/89	09:00	9.23	18708	1.52	43.59	0.73
BTT	05/06/89	15:00	7.78	18360	1.50	45.87	0.7
BTT	05/07/89	03:00	6.96	18169	1.49	45.33	0.7
BTT	05/07/89	21:00	6.19	18144	1.49	45.64	0.7
BTT	05/08/89	13:45	3.38	18418	1.50	45.97	0.7
BTT	05/19/89	09:30	2.42	18476	1.51	58.74	0.62

APPENDIX

Baseflow and Storm Sampling Results for BTT (cont)

LOCATION	DATE	TIME	DISSOLVED Cs-137 pCi/L	1 Sigma Counting Error	PARTIC. Cs-137 pCi/L	1 Sigma Counting Error
BTT	01/23/89	15:45	676	57	10	5
BTT	02/13/89	16:00	171	39		
BTT	02/14/89	11:00	312	45		
BTT	02/14/89	13:00	267	42		
BTT	02/14/89	20:00	184	39		
BTT	02/15/89	12:00	414	47		
BTT	02/16/89	07:00	251	42		
BTT	02/16/89	11:00	303	41		
BTT	02/16/89	20:00	321	37	88	20
BTT	02/17/89	04:00	140	28		
BTT	02/17/89	09:00	122	25	288	30
BTT	02/17/89	14:00	224	37		
BTT	02/17/89	18:00	138	35	620	45
BTT	02/17/89	22:00	319	39		
BTT	02/18/89	02:00	673	55	235	28
BTT	02/18/89	06:00	891	51	219	29
BTT	02/18/89	10:00	1066	65	190	18
BTT	02/18/89	14:00	1231	73	143	18
BTT	02/19/89	00:00	1142	68	123	18
BTT	02/19/89	12:00	1111	70		
BTT	02/20/89	04:00	1288	60	80	13
BTT	02/20/89	10:00	168	30	2553	93
BTT	02/20/89	14:00	1193	71	113	18
BTT	02/21/89	02:00	1480	78	115	23
BTT	02/21/89	03:00	78	22	4568	148
BTT	02/21/89	06:00	822	59	800	48
BTT	02/21/89	10:00	1657	79	171	17
BTT	02/21/89	13:00	2066	98		
BTT	02/21/89	19:00	2267	108		
BTT	02/22/89	02:00	2169	97	120	18
BTT	02/22/89	10:00	2040	92		
BTT	02/23/89	06:00	1561	80	48	13
BTT	02/24/89	13:10	867	67	48	10

APPENDIX

Baseflow and Storm Sampling Results for BTT (cont)

LOCATION	DATE	TIME	DISSOLVED Cs-137 pCi/L	1 Sigma Counting Error	PARTIC. Cs-137 pCi/L	1 Sigma Counting Error
BTT	03/17/89	09:35	341	38		
BTT	03/18/89	06:00				
BTT	03/18/89	10:00				
BTT	03/18/89	11:30	27	27		
BTT	03/18/89	12:00				
BTT	03/18/89	13:00				
BTT	03/18/89	14:00	202	52		
BTT	03/20/89	10:00	293	41		
BTT	03/21/89	09:20	265	37		
BTT	03/22/89	10:10	190	36		
BTT	04/27/89	13:50	618	53	48	8
BTT	05/04/89	14:00				
BTT	05/05/89	10:00				
BTT	05/05/89	13:00				
BTT	05/05/89	15:00				
BTT	05/05/89	16:00				
BTT	05/05/89	20:00				
BTT	05/05/89	21:00				
BTT	05/06/89	00:00	166	22		
BTT	05/06/89	04:00				
BTT	05/06/89	07:00				
BTT	05/06/89	09:00				
BTT	05/06/89	15:00				
BTT	05/07/89	03:00	88	11		
BTT	05/07/89	21:00	117	38		
BTT	05/08/89	13:45	203	41		
BTT	05/19/89	09:30				

APPENDIX

Baseflow and Storm Sampling Results for MS1

LOCATION	DATE	TIME	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
MS1	01/23/89	16:10	12855	1.26	14588	0.05
MS1	02/13/89	15:00	12563	1.25	14068	0.05
MS1	02/13/89	16:00				
MS1	02/14/89	11:00				
MS1	02/14/89	13:00				
MS1	02/14/89	21:00				
MS1	02/15/89	12:00				
MS1	02/16/89	11:00	12963	1.27	13503	0.05
MS1	02/16/89	20:00	12771	1.26		
MS1	02/17/89	06:00	13263	1.28	13622	0.05
MS1	02/17/89	09:00	12088	1.22	10348	0.05
MS1	02/17/89	11:00	11139	1.18		
MS1	02/17/89	14:00	10439	1.14	9324	0.05
MS1	02/17/89	17:00	9081	1.07		
MS1	02/17/89	20:00	8614	1.04	9338	0.05
MS1	02/17/89	22:00	7798	0.99	9315	0.05
MS1	02/18/89	00:00	7565	0.98	9561	0.05
MS1	02/18/89	04:00	8014	1.00	9718	0.05
MS1	02/18/89	08:00	8723	1.05	9780	0.05
MS1	02/18/89	16:00	10414	1.14	9649	0.05
MS1	02/19/89	04:00	11580	1.20	9726	0.05
MS1	02/19/89	16:00	12580	1.25	9990	0.05
MS1	02/20/89	04:00	12605	1.25	10388	0.05
MS1	02/20/89	10:00	12372	1.24	8806	0.05
MS1	02/20/89	12:00	10697	1.15	6115	0.05
MS1	02/20/89	16:00	11547	1.20	8780	0.05
MS1	02/21/89	02:00	11255	1.18	10351	0.05
MS1	02/21/89	03:00	9672	1.10	8126	0.05
MS1	02/21/89	04:00	5049	0.81	2771	0.09
MS1	02/21/89	06:00	7081	0.95	6489	0.05
MS1	02/21/89	08:00	6965	0.94	6205	0.05
MS1	02/21/89	10:00	7506	0.97	6659	0.05
MS1	02/21/89	13:00	8756	1.05		
MS1	02/21/89	16:00	9481	1.09	6894	0.05
MS1	02/22/89	00:00	11289	1.18	7429	0.05
MS1	02/22/89	10:00	12038	1.22		
MS1	02/22/89	20:00	12430	1.24	7924	0.05
MS1	02/23/89	12:00	12630	1.25		
MS1	02/24/89	13:25	12596	1.25	8695	0.05

APPENDIX

Baseflow and Storm Sampling Results for MS1 (cont)

LOCATION	DATE	TIME	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
MS1	03/17/89	09:50	12789	1.26	11236	0.05
MS1	03/18/89	06:00				
MS1	03/18/89	10:00				
MS1	03/18/89	12:00				
MS1	03/18/89	13:00				
MS1	03/18/89	14:00				
MS1	03/18/89	16:00				
MS1	03/20/89	11:00				
MS1	03/20/89	23:00				
MS1	03/21/89	01:00				
MS1	03/21/89	02:00				
MS1	03/21/89	03:00				
MS1	03/21/89	06:00				
MS1	03/21/89	10:00				
MS1	03/22/89	10:45	9855	1.11	16526	0.05
MS1	04/27/89	14:15	13071	1.27	17839	0.05
MS1	05/04/89	15:00	11969	1.22	14394	0.05
MS1	05/05/89	14:00	6773	0.93	5113	0.06
MS1	05/05/89	15:15	7080	0.95	7262	0.05
MS1	05/05/89	17:00	7719	0.99	9476	0.05
MS1	05/06/89	08:30	8649	1.04	13893	0.05
MS1	05/06/89	11:00	9147	1.07	14475	0.05
MS1	05/06/89	18:00	9836	1.11	15745	0.05
MS1	05/08/89	13:00	11212	1.18	17573	0.05
MS1	05/19/89	09:50	13247	1.28	15366	0.05

APPENDIX

Baseflow and Storm Sampling Results for MS1 (cont)

LOCATION	DATE	TIME	DISCHARGE (Transducer) L/min	DISCHARGE (Gaged) L/min	DISSOLVED Cs-137 pCi/L	PARTIC. Cs-137 pCi/L
MS1	01/23/89	16:10		69.76	ND	
MS1	02/13/89	15:00	184.68		ND	
MS1	02/13/89	16:00	184.68		ND	
MS1	02/14/89	11:00	174.48		ND	
MS1	02/14/89	13:00	184.68		ND	
MS1	02/14/89	21:00	167.7		ND	
MS1	02/15/89	12:00	110.16		ND	
MS1	02/16/89	11:00	147	91.69	ND	
MS1	02/16/89	20:00	167.7		ND	
MS1	02/17/89	06:00	254.16		ND	
MS1	02/17/89	09:00	372.9		ND	
MS1	02/17/89	11:00	536.04		ND	
MS1	02/17/89	14:00	494.22		ND	
MS1	02/17/89	17:00	752.1		ND	
MS1	02/17/89	20:00	1083.42		ND	
MS1	02/17/89	22:00	1365.6		ND	
MS1	02/18/89	00:00	1219.5		ND	
MS1	02/18/89	04:00	952.26		ND	
MS1	02/18/89	08:00	780.66		ND	
MS1	02/18/89	16:00	549.3		ND	
MS1	02/19/89	04:00	397.2		ND	
MS1	02/19/89	16:00	305.46		ND	
MS1	02/20/89	04:00	262.68		ND	
MS1	02/20/89	10:00	640.32		ND	
MS1	02/20/89	12:00	716.28		ND	
MS1	02/20/89	16:00	454.5		ND	
MS1	02/21/89	02:00	362.4		ND	
MS1	02/21/89	03:00	1033.62		ND	
MS1	02/21/89	04:00	4480.14		ND	
MS1	02/21/89	06:00	2483.88		ND	
MS1	02/21/89	08:00	1851.84		ND	
MS1	02/21/89	10:00	1252.32		ND	
MS1	02/21/89	13:00	892.8		ND	
MS1	02/21/89	16:00	700.68		ND	
MS1	02/22/89	00:00	475.68		24+17	
MS1	02/22/89	10:00	346.92		ND	
MS1	02/22/89	20:00	298.32		ND	
MS1	02/23/89	12:00	275.76		ND	
MS1	02/24/89	13:25	275.76	137.54	ND	

ND = Not Detected

APPENDIX

Baseflow and Storm Sampling Results for MS1 (cont)

LOCATION	DATE	TIME	DISCHARGE (Transducer) L/min	DISCHARGE (Gaged) L/min	DISSOLVED Cs-137 pCi/L	PARTIC. Cs-137 pCi/L
MS1	03/17/89	09:50		16.34	ND	ND
MS1	03/18/89	06:00				
MS1	03/18/89	10:00				
MS1	03/18/89	12:00				
MS1	03/18/89	13:00				
MS1	03/18/89	14:00				
MS1	03/18/89	16:00				
MS1	03/20/89	11:00				
MS1	03/20/89	23:00				
MS1	03/21/89	01:00				
MS1	03/21/89	02:00				
MS1	03/21/89	03:00				
MS1	03/21/89	06:00				
MS1	03/21/89	10:00		413		
MS1	03/22/89	10:45		15.67	ND	
MS1	04/27/89	14:15	(19.26)	17.88	ND	ND
MS1	05/04/89	15:00	17.7			
MS1	05/05/89	14:00	1442.4			
MS1	05/05/89	15:15	1203.18			
MS1	05/05/89	17:00	924.6			
MS1	05/06/89	08:30	336.9			
MS1	05/06/89	11:00	284.76			
MS1	05/06/89	18:00	191.82			
MS1	05/08/89	13:00	71.88			
MS1	05/19/89	09:50	29.04	27.97		

ND = Not Detected

APPENDIX

Baseflow and Storm Sampling Results for HRTV and HRTF

LOCATION	DATE	TIME	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
HRTV	01/23/89	16:40	289	0.28	0.93	14.41
HRTV	02/24/89	14:00	305	0.28	1.25	11.89
HRTV	03/17/89	11:05	264	0.27	0.92	15.72
HRTV	04/27/89	13:00	322	0.28	0.82	17.7
HRTV	05/05/89	12:00	169	0.25	0.87	13.16
HRTV	05/06/89	10:30	380	0.30	1.27	9.19
HRTV	05/08/89	12:10	321	0.28	1.17	9.92
HRTV	05/19/89	08:25	194	0.26	1.1	10.39
HRTF	01/23/89	16:50	438	0.31	3926	0.08
HRTF	02/24/89	14:10	389	0.30	4014	0.08
HRTF	03/17/89	11:10	488	0.32	6469	0.06
HRTF	04/27/89	13:05	654	0.35	14410	0.05
HRTF	05/04/89	14:00	600	0.34	7415	0.05
HRTF	05/05/89	10:00	515	0.32	6049	0.05
HRTF	05/05/89	11:00	279	0.28	3663	0.1
HRTF	05/05/89	12:00	127	0.24	1176	0.13
HRTF	05/05/89	15:00	118	0.24	978	0.22
HRTF	05/05/89	17:00	144	0.24	1100	0.14
HRTF	05/05/89	20:00	177	0.25	1277	0.13
HRTF	05/05/89	21:00	127	0.24	961	0.14
HRTF	05/05/89	23:00	228	0.26	1205	0.13
HRTF	05/06/89	04:00	203	0.26	1408	0.12
HRTF	05/06/89	10:00	177	0.25	1726	0.11
HRTF	05/06/89	15:00	237	0.27	2166	0.09
HRTF	05/06/89	23:00	270	0.27	2670	0.09
HRTF	05/08/89	12:15	431	0.31	4167	0.07
HRTF	05/19/89	08:40	558	0.33	7078	0.05

APPENDIX

Baseflow and Storm Sampling Results for HRTV and HRTF (cont)

LOCATION	DATE	TIME	DISCHARGE L/min	DISSOLVED Cs-137 pCi/L	PARTIC. Cs-137 pCi/L	1 Sigma Counting Error
HRTV	01/23/89	16:40	294	ND	27.5	7
HRTV	02/24/89	14:00	370	ND	ND	
HRTV	03/17/89	11:05	237	ND	ND	
HRTV	04/27/89	13:00	75	ND		
HRTV	05/05/89	12:00	4430			
HRTV	05/06/89	10:30	1115	ND		
HRTV	05/08/89	12:10	315	ND		
HRTV	05/19/89	08:25	157	ND		
HRTF	01/23/89	16:50		ND	35	10
HRTF	02/24/89	14:10		ND	ND	
HRTF	03/17/89	11:10		ND	ND	
HRTF	04/27/89	13:05	114	ND		
HRTF	05/04/89	14:00	295	ND		
HRTF	05/05/89	10:00	439	ND		
HRTF	05/05/89	11:00	1601			
HRTF	05/05/89	12:00	8074	ND		
HRTF	05/05/89	15:00	7609			
HRTF	05/05/89	17:00	6266	137+21		
HRTF	05/05/89	20:00	3986	ND		
HRTF	05/05/89	21:00	6353	ND		
HRTF	05/05/89	23:00	4121	ND		
HRTF	05/06/89	04:00	2920	ND		
HRTF	05/06/89	10:00	2234	ND		
HRTF	05/06/89	15:00	1561	ND		
HRTF	05/06/89	23:00	1185	ND		
HRTF	05/08/89	12:15	604	ND		
HRTF	05/19/89	08:40	178	ND		

ND = Not Detected

APPENDIX

Baseflow and Storm Sampling Results for T2A

LOCATION	DATE	TIME	DISCHARGE L/min	Sr-90 pCi/L	1 Sigma Counting Error	H-3 nCi/L	1 Sigma Counting Error
T2A	01/23/89	1630	55.95	8822	1.05	10394	0.05
T2A	02/13/89	1500	82.8	8931	1.05	10619	0.05
T2A	02/17/89	920	434.76	8738	1.04	9335	0.05
T2A	02/17/89	1410	564.72	8663	1.04	7806	0.05
T2A	02/18/89	1545	700.68	7541	0.97	7621	0.05
T2A	02/21/89	1603	1007.34	6972	0.94	5516	0.06
T2A	02/24/89	1345	127.89	8529	1.03	6744	0.05
T2A	03/17/89	1130	38.38	9107	1.06	8088	0.05
T2A	03/18/89	1230	596				
T2A	03/21/89	1020	497				
T2A	04/27/89	13:30	11.78	9785	1.10	12559	0.05
T2A	05/06/89	10:40	386.52	7399	0.96	9988	0.05
T2A	05/08/89	14:15	55.95	8705	1.04	11694	0.05
T2A	05/19/89	08:55	16.28	9626	1.09	11034	0.05

APPENDIX

Baseflow and Storm Sampling Results for T2A (cont)

LOCATION	DATE	TIME	DISSOLVED Cs-137 pCi/L	1 Sigma Counting Error	PARTIC. Cs-137 pCi/L	1 Sigma Counting Error
T2A	01/23/89	1630	ND			
T2A	02/13/89	1500	ND			
T2A	02/17/89	920	ND			
T2A	02/17/89	1410	ND			
T2A	02/18/89	1545	ND			
T2A	02/21/89	1603	ND			
T2A	02/24/89	1345	ND			
T2A	03/17/89	1130	61	31		
T2A	03/18/89	1230				
T2A	03/21/89	1020				
T2A	04/27/89	13:30	5	48	195	23
T2A	05/06/89	10:40				
T2A	05/08/89	14:15				
T2A	05/19/89	08:55				

ND = Not Detected

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